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By ALFRED RUSSEL WALLACE

AND

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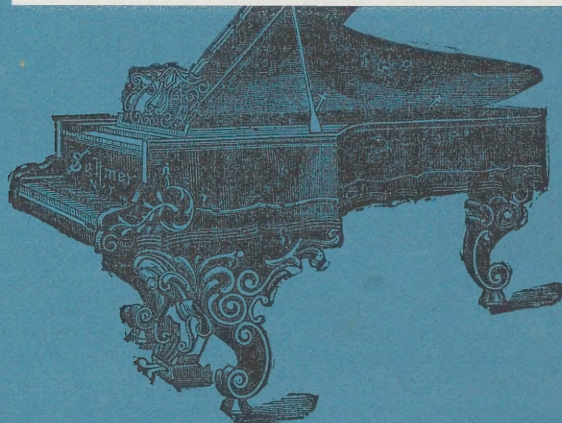
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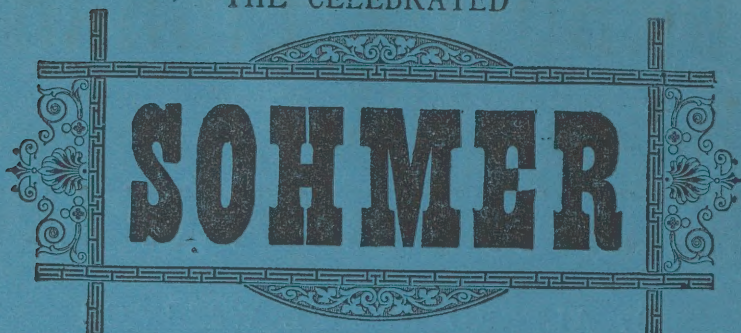
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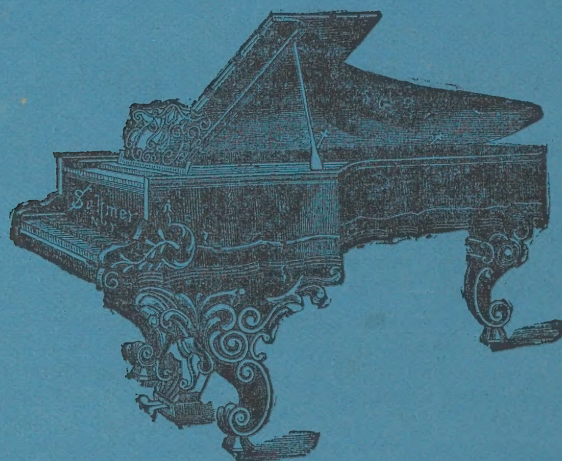
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THE DISTRIBUTION OF LIFE, ANIMAL AND VEGETABLE, IN SPACE AND TIME.

BY ALFRED RUSSEL WALLACE AND W. T. THISELTON DYER.

SCOPE AND BEARING OF THE SUBJECT.

So long as each species of organism was supposed to have had an independent origin, the place it occupied on the earth's surface or the epoch where it first appeared had little significance. It was, indeed, perceived that the organization and constitution of each animal or plant must be adapted to the physical conditions in which it was placed; but this consideration only accounted for a few of the broader features of distribution, while the great body of the facts, their countless anomalies and curious details, remained wholly inexplicable. But the theory of evolution and gradual development of organic forms by descent and variation (some form of which is now universally accepted by men of science) completely changes the aspect of the question and invests the facts of distribution with special

importance. The *time* when a group or a species first appeared, the *place* of its origin, and the *area* it now occupies upon the earth, become essential portions of the history of the universe. The course of study initiated and so largely developed by Mr. Darwin has now shown us the marvelous interdependence of every part of nature. Not only is each organism necessarily related to and affected by all things, living and dead, that surround it, but every detail of form and structure, of color, food, and habits, must—it is now held—have been developed in harmony with, and to a great extent as a result of, the organic and inorganic environments. Distribution becomes, therefore, as essential a part of the science of life as anatomy or physiology. It shows us, as it were, the form and structure of the life of the world considered as one vast organism, and it enables us to comprehend, however imperfectly, the processes of

development and variation during past ages which have resulted in the actual state of things. It thus affords one of the best tests of the truth of our theories of development; because the countless facts presented by the distribution of living things in present and past time must be explicable in accordance with any true theory, or at least must never directly contradict it.

From these indications of the scope and bearing of the subject, it will be seen that its full and adequate treatment would require volumes, and would necessarily involve an amount of details only suited to specialists in the various branches of natural history. All that can be attempted here is to give such a general sketch of the whole subject as to place the reader in possession of the main results arrived at, and enable him to comprehend the bearing of the more detailed information he may meet with elsewhere.

The three great heads under which the various matters connected with distribution may be classed are—1st, the geographical distribution of living organisms; 2d, the geographical distribution of extinct organisms; and 3d, the geological succession of the chief forms of life. Owing, however, to the fact that the study of animals and of plants forms very distinct sciences, and that there are special peculiarities in the phenomena presented by each which require to be carefully discriminated, it is found to be necessary to make a primary division of the subject into the distribution of animals and of plants respectively.

SECTION I.

DISTRIBUTION OF ANIMALS.

THE distribution of living animals in space naturally forms the first division of our subject, both because the phenomena are simpler and better known, and because it puts before us

the main problems and difficulties to the solution of which the other divisions furnish the key. Animals may be roughly divided into two great series, broadly distinguished as regards their mode of life—the terrestrial and the aquatic; and for the purpose of our present study these divisions are of primary importance, because that element which limits the range of the one class offers a free passage to the migrations of the other, and *vice versa*. The first series is by far the most important. It is the best known, and includes almost all the higher animals; while the variety and interest of the various land divisions of the globe are far greater than in the case of that portion of its surface covered by water. We shall therefore consider first, and with a greater amount of detail, the distribution of land animals, including among them the fresh-water forms whose range is limited by the same general conditions.

THE GEOGRAPHICAL DISTRIBUTION OF LAND ANIMALS.

As soon as we begin to examine into the distribution of animals over the land surface of the globe, we meet with two very distinct and sometimes conflicting classes of facts, which may be conveniently grouped as *climatal* and *geographical* distribution. The first is the most obvious, and was long considered to be the most essential, since we find that not only many species, as the polar bear and musk sheep, are strictly limited to cold countries, and others, as the tapir, to warm, but that entire groups, as the sheep on the one hand and the trogons on the other, seem almost equally dependent on temperature. But when we come to compare the productions of the several continents, we find a set of differences in which climate appears to play no part. Thus, almost the whole of the warblers (*Sylviidae*) of Europe and North Asia are absent in similar climates in North America, their place being taken by a totally distinct family, the wood-warblers

(*Mniotiltidae*); the ant-eaters, sloths, and tapirs of tropical America are replaced in tropical Africa by aard-varks (*Orycteropus*), lemurs, and hippopotami; while islands like Borneo and New Guinea, situated in the same ocean not very far apart, and whose climates and physical conditions are, as nearly as possible, identical, are yet as radically different in their chief forms of animal life as are remote countries situated respectively in the cold and tropical zones. It is evident then, that although climate has a certain amount of influence on the distribution of animal forms, yet geographical conditions are far more important. There is reason to believe that the direct action of climate on animal life is far less effective than its indirect action through the limitation of the variety and quantity of vegetable and insect food; whereas geographical isolation has led to diversity of type by its influence on development during successive ages, as pointed out by Mr. Darwin (*Origin of Species*, HUMBOLDT LIBRARY edition, par. 145). It follows that zoological regions, or those primary divisions of the earth characterized by distinct assemblages of animals, will, for the most part, coincide with natural geographical divisions. They do not, however, conform to the actual divisions of our geographies, because these are often political or ethnographical, rather than physical—as in the separation of Europe from Asia. In another case, the coincidence of a mountain chain (the Himalayas) and the plateau of Thibet, with the demarcation of the tropical and temperate zones, forms a zoological division across a continent almost as complete as would be effected by a considerable extent of ocean.

A. Vertical Distribution of Animals.

—Besides the horizontal distribution dependent on the various causes just indicated, the range of animals is more or less determined by the altitude of the land surface above, or its depth below the sea level. As we ascend lofty mountains, the forms of

life change in a manner somewhat analogous to the changes observed in passing from a warm to a cold country. This change is, however, far less observable in animals than in plants; and it is so unequal in its action, and can so frequently be traced to mere change of climate and deficiency of food, that it must rank as a phenomenon of secondary importance. Vertical distribution among animals will be found in most cases to affect species rather than generic or family groups, and to involve in each case a mass of local details which can hardly be introduced in a general sketch of the whole subject of distribution. The same remarks apply to the bathymetrical zones of marine life. Many groups are confined to tidal, or shallow, or deeper waters; but these differences of habit are hardly “geographical,” but involve details, suited rather to the special study of individual groups than to such a general outline of the distribution of the animal kingdom as we are here attempting to lay before our readers.

B. Powers of Dispersal of Animals.

—Animals differ greatly in their powers of dispersal or migration; and this is an important element in determining the causes of their actual distribution. Mammalia as a class are more limited in this respect than birds; because the former have no means of passing over seas and oceans, or, with few exceptions, over lofty mountains or arid deserts, all of which when of moderate width can be easily traversed by many birds. Reptiles in their adult state are almost as restricted in their powers of dispersal as mammals, but most of them being oviparous, their eggs may be floated on drift-wood over seas and straits, or even, in rare cases, be carried by birds; whereas the young of Mammalia are for some time wholly dependent on their parents. Amphibia and fresh-water fishes have yet another advantage, that many of them can endure great cold, and their ova may sometimes be frozen without injury. Thus floating ice becomes an important agent in their dispersal, and

enables us to account for the curious fact that their distribution often differs in a remarkable manner from that of the three higher classes of vertebrates. When we come to insects, we find the power of dispersal (as regards land animals) at a maximum; for not only can they travel by almost every mode available to other groups, but their small size, low specific gravity, and (in many cases) great tenacity of life, give them altogether exceptional advantages in this respect. They are easily carried for great distances through the air by gales and storms; and there is evidence to show that many remote islands have been thus stocked, and that many wide-spread groups owe their extensive range to this cause. Others can float uninjured for many days at sea; while their eggs or larvæ, inclosed in crevices of tree-trunks or concealed under bark, may be carried for hundreds or even thousands of miles by surface currents across extensive seas (Wallace, *Geographical Distribution of Animals*, vol. i. pp. 32, 209-214). The fact, then, that these small creatures have often a more extensive range, and present anomalies in their distribution, than larger animals, is only what we might expect; and if we keep their unusual powers of dispersal ever present to our minds, we shall be able to account for most of the anomalies they present, and thus bring them under the same general classification of the phenomena of distribution which is most serviceable in studying the history of the higher animals.

But the actual power of dispersal is by no means the only factor in determining the distribution of a species or a group. It is no use to bring a creature to a new country if it cannot live and maintain itself there. Whether it can do so depends upon many causes. It must be able to adapt itself to a different climate, and generally to different physical conditions; it must be able to live upon whatever food it may find in its new abode; and, most important of all, it must be able to defend itself against new kinds of ene-

mies and to live in successful competition with allied organisms which are already in possession of the soil.

C. Wide-spread and Local Groups.—There is much reason to believe that the last-mentioned condition is the most difficult for an intruder to fulfill, and that a large proportion of the immigrants which from any cause arrive in a new country are unable to maintain themselves in it, not because the country itself is not well adapted to their wants, but solely because it is already occupied by other creatures somewhat better adapted to all the surrounding conditions. Hence arise the phenomena of wide-spread or dominant species, and others which are exceedingly local and often rare, that is, consisting of but a small group of individuals. The former are best adapted to the entire environment, and are generally increasing their numbers and area of distribution; the latter are less perfectly adapted, and probably diminishing in numbers and on the road to final extinction. The power of adaptation seems, generally speaking, to be in an inverse ratio to the power of dispersal. The larger Mammalia and many birds are capable of enduring a great variety of climates, and even of maintaining themselves in many new countries in competition with the native inhabitants. Thus horses and cattle from the Old World have run wild and greatly multiplied in both North and South America, and are probably capable of existing in any country where there is a sufficiency of open uncultivated land. Insects, on the other hand, are often dependent on some one kind of vegetable food, are especially liable to injuries by climate, and unless very numerous would be liable to be at once exterminated by their various enemies.

D. Barriers which Limit the Distribution of Animals.—These are of many kinds, and affect the several groups in unequal degrees. The nature of the vegetation alone determines the range of a number of animals. Deserts, marshes, open plains, and especially

forests, have each their peculiar inhabitants, which can hardly stray far beyond their limits. This is particularly the case with the tropical forests, whose perennial foliage and almost perennial succession of flowers and fruits supply the wants of an immense number of peculiar forms of life. These forests are, in fact, the home of all that is most characteristic of the tropics, and their limits form the dividing lines between very distinct faunas. Rivers, when very large, also determine the range of many species, but this is probably because their valleys have been once arms of the sea separating districts with somewhat different faunas. Mountains, when rising to a great height in unbroken ranges, form an impassable barrier to many groups; but their geological age is also an important factor, and they are seldom so ancient and so continuous as to form absolute barriers. Climate, whether determined by latitude or by elevation above the sea, is also a very effective barrier, though probably its action is indirect, and is determined by its influence on vegetation, and by bringing diverse groups into competition. The limits of the tropical and temperate zones, generally marked out by more or less extensive deserts, form the boundary between regions or sub-regions all round the globe. Oceans are, however, by far the most important barriers; and this is due not only to their great extent and general impassability to land animals, but also to their enormous antiquity, so that for countless ages they have separated the faunas of remote continents from each other.

In accordance with these principles, it is found, that continents separated by the widest and deepest oceans differ most radically in the entire series of their animals; while those which are less completely separated, or which are only divided by climatal differences or by mountain ranges, are less unlike in their chief forms of life. Thus are constituted zoological regions, which represent the most permanent geographical

features of the globe, and afford us an indication of that permanence in the isolation and peculiarity of their animal inhabitants.

E. Zoological Reasons.—Although there is some difference of opinion as to the number and limits of the primary divisions of the earth termed regions, the following are now generally admitted to be the most satisfactory. They are nearly identical with those first proposed by Mr. P. L. Sclater in 1857.

1. The Palæarctic Region, which includes all Europe to the Azores and Iceland, all temperate Asia from the high Himalayas and west of the Indus, with Japan, and China from Ningpo and to the north of the watershed of the Yang-tse-kiang; also North Africa and Arabia, to about the line of the tropic of Cancer. This may be popularly called the European region, Europe being the richest and most varied portion of it, and containing representatives of all the more important types; but it must not be forgotten that the region includes a much larger area in Asia, and that there are many peculiar North Asiatic animals.

2. The Ethiopian Region, which includes all Africa south of the tropic of Cancer, as well as the southern part of Arabia, with Madagascar and the adjacent islands. It may be popularly termed the African Region.

3. The Oriental Region, which is comparatively small, including India and Ceylon, the Indo-Chinese countries and southern China, and the Malay Archipelago as far as the Philippines, Borneo, and Java. It may be popularly called the South Asiatic or Indian region.

4. The Australian Region, which is composed of the remainder of the Malay Archipelago, Australia, New Zealand, and all the tropical islands of the Pacific, as far east as the Marquesas and the Low Archipelago.

5. The Neotropical Region, which comprises the whole of South America and the adjacent islands, the West Indies or Antilles, and the tropical parts of Central America and Mexico. It may be well called the South American region.

6. The Nearctic Region, which consists of all temperate and arctic North America, with Greenland, and is thus well described as the North American region.

These six regions, although all of primary importance from their extent, and well marked by their total assemblage of animal forms, vary greatly in their zoological richness, their degree of isolation, and their relationship to each other. The Australian region is the most peculiar and the most isolated, but it is comparatively small, and poor in the higher animals. The Neotropical region comes next in peculiarity and isolation, but it is extensive and excessively rich in all forms of life. The Ethiopian and Oriental regions are also very rich, but they have much in common. The Palearctic and Nearctic regions, being wholly temperate, are less rich, and they too have many resemblances to each other; but while the Nearctic region has many groups in common with the Neotropical, the Palearctic is closely connected with the Oriental and Ethiopian regions. The cause of these various resemblances and differences depends on the past history of the earth, and will be better understood when we have sketched the zoological features of each region and the changes they have undergone in the latest geological periods.

The Palearctic Region.—This extensive region, though varied in physical aspect, and often covered with luxuriant vegetation, is poor in animal life when compared with the great tropical regions of the Old and New Worlds. This is no doubt due mainly to climate, but also in part to so much of its surface being densely populated and highly cultivated. It contains, however, a number of characteristic and not a few altogether peculiar animal forms. Beginning with the Mammalia, we have first the sheep and goats with such allied forms as the chamois and saiga-antelope, which are especially characteristic; deer are abundant and varied; the smaller cats, the wolves, the foxes, and the bears abound, with a variety of smaller groups, as weasels, badgers, and some otters. Seals are plentiful on the northern coast, and even in the Black and Caspian seas; wild horses and

asses abound in Asia, as they once did in Europe; there are many peculiar forms of mice, voles, and hamsters; while dormice, squirrels, marmots, hares, and pikas are well-marked features of the region. The insectivorous family of the moles is almost peculiar, as are the curious mole rats (*Spalax*). The genera which are peculiar to the Palearctic region belong to the following families:—to the moles (*Talpidae*) 7 genera; to the dogs (*Canidae*) 1 genus; to the weasels (*Mustelidae*) 3 genera; to the pandas (*Eluridae*) 1 genus; to the seals (*Phocidae*) 1 genus; to the camels (*Camelidae*) 1 genus; to the deer (*Cervidae*) 6 genera; to the hollow-horned ruminants (*Bovidae*) 7 genera; to the rats (*Muridae*) 6 genera; to the mole-rats (*Spalacidae*) 2 genera; to the *Octodontidae*, a peculiar group of rat-like animals only found in South America, Abyssinia, and North Africa, 1 genus.

In birds, the Palearctic region is pre-eminently rich in thrushes, warblers, titmice, jays and magpies, sparrows, and buntings. It also abounds in grouse, and in its eastern half in magnificent pheasants. Water-birds are plentiful, and its northern districts produce many fine ducks and divers. The following enumeration of the families of which the Palearctic region possesses peculiar genera will help to give an idea of the characteristic features of its ornithology:—Of the warblers (*Sylviidae*) 15 genera, many of which, however, migrate into tropical Africa and India in winter; of babblers (*Timaliidae*) 1 genus; of reedlings (*Panuridae*) 4 genera; of creepers (*Certhiidae*) 1 genus; of tits (*Paridae*) 1 genus; of the crow family (*Corvidae*) 4 genera; of finches and buntings (*Fringillidae*) 12 genera; of starlings (*Sturnidae*) 1 genus; of larks (*Alaudidae*) 2 genera; of sand-grouse (*Pteroclididae*) 1 genus; of grouse (*Tetraonidae*) 4 genera; of pheasants (*Phasianidae*) 5 genera; of vultures (*Vulturidae*) 1 genus; of rails (*Rallidae*) 1 genus; of snipes (*Scolopacidae*) 4 genera; of coursers (*Glaucolidae*) 1

genus; of bustards (*Otididae*) 1 genus. Of the remaining groups less accurate information is obtainable, and their distribution is less generally interesting. Reptiles, being heat-loving animals, are comparatively scarce, yet in the desert regions they are more plentiful and furnish a considerable number of peculiar types, there being two genera of snakes and four of lizards not found in any other region. All reptiles diminish rapidly as we go north, and cease before we reach the arctic circle. The common viper reaches 67° N. lat. in Scandinavia, the northern limit of reptiles in the region. Amphibia are much more patient of cold, the common frog ranging to the extreme north of Europe. There are no less than 16 peculiar genera of Amphibia, 8 of the tailed and 8 of the tailless group, the most remarkable being the *Proteus*, found only in subterranean lakes in Carniola and Carinthia.

Of fresh-water fishes about 20 genera are wholly confined to the region, of which the perches (*Percidae*) have 3 genera; the salmons and trout (*Salmonidae*) 3 genera; the carp (*Cyprinidae*) 13 genera; with a peculiar genus and family (*Comephorus*) found in Lake Baikal, and another (*Tellia*) belonging to the *Cyprinodontidae*, in the Atlas Mountains.

Insects are so extensive a class that the barest enumeration of their most remarkable forms would be out of place in such a sketch as this. We can only mention that, although butterflies are not very numerous, yet no less than 15 genera are peculiar to the region. Beetles, however, abound, and the most characteristic Palæarctic group is undoubtedly the *Carabidae*, or predaceous ground-beetles, which are more predominant here than in any other region, and are also of larger average size—a most unusual circumstance in the insects of a temperate as compared with those of tropical regions.

Land shells are tolerably numerous both in species and individuals, but are of small size and little beauty as

compared with those of warmer countries. Very few of the genera are peculiar.

The total number of the generic forms of Vertebrata peculiar to the Palæarctic region is, as nearly as can be estimated, 138,—a very large number when we consider the general severity of the winter, and the circumstance, that along its whole southern margin this region is bounded by tropical lands with no absolute barrier against intermigration. The amount of peculiarity may be even better estimated by the fact that, out of a total of 274 genera of Mammalia and birds inhabiting the region, 87, or somewhat less than one-third, are confined to it. This mode of estimating the zoological character of a region by *genera*, gives a far truer idea than any enumeration of peculiar *species*, because the former imply more radical and important differences than the latter.

Subdivisions of the Palæarctic Region.

—The general zoological characters here given apply with considerable uniformity to the whole of the Palæarctic region, the similarities being of course greater where climate and physical conditions generally correspond. Thus, even between such remote islands as Great Britain and Yesso (North Japan) there is a wonderful similarity in the general forms of life, many of our most familiar birds and insects reappearing at the other extremity of the region under identical or but slightly modified forms. Owing perhaps to the great climatal changes the north temperate zone has undergone in recent geological times, and the vast amount of migration thereby produced, as well as to the absence of any continuous barriers, it is very difficult to mark out with accuracy the zoological subdivisions of this region. Certain broad divisions, depending partly on climate, partly on physical feature, and partly on geographical proximity to other regions, may, however, be indicated.

Europe, north of the Pyrenees, Alps, Balkans, and Caucasus, may perhaps be considered as the most typical portion of the Palæarctic region, possessing most of its characteristic features in their full development. It may be termed the European sub-region. South of this comes

the Mediterranean sub-region, including South Europe and North Africa, which wonderfully resemble each other in all their chief forms of animal life, although some few purely African species are found south of the Mediterranean. This sub-region includes also Asia Minor and Persia, with Syria and Northern Arabia. It is chiefly characterized by a number of desert forms, such as gazelles, civets, jerboas, quails, desert-larks, and numerous lizards; and by a number of species which cannot endure the colder climate of the north, as porcupines, monkeys, ichneumons, and a host of peculiar groups of insects. To this region belong the Atlantic islands from the Azores to the Canaries, the animal productions of all of them being closely related to those of South Europe or North Africa. It is a curious fact that the remotest of these islands, the Azores, offer less peculiarity in their birds and insects than Madeira and the Canaries, which are so much nearer the continent; but this is sufficiently explained by the greater prevalence of storms and gales in the more northern latitude of the Azores, and helps to prove that aerial currents are the chief means by which these two classes of animals are dispersed. For a discussion of this interesting subject and its bearing on the theories of distribution and development, see Wallace, *Geographical Distribution of Animals*, vol. i. p. 206.

The northern part of Asia differs very little in the main features of its zoology from the corresponding parts of Europe, but as we approach the northern slopes of the great plateau of Central Asia many peculiar forms occur, as wild horse, pikas (*Lagomys*) starlings of the genus *Podoces*, and many others. The great desert plateaus of Thibet and Mongolia form another subdivision, with many peculiar forms. Here are found the yak, some peculiar antelopes, with wild sheep and goats, and several peculiar rodents; and among birds many peculiar forms of grouse, partridges, and pheasants.

Another well-marked division is formed by the temperate portion of Eastern Asia, comprising Japan, Manchuria, Northern and Central China, with parts of East Thibet and the higher portions of the Himalayas as far west as Nepal. This is a fertile and luxuriant district which receives several tropical forms of life from the adjoining Oriental region. It is rich in Insectivora and in deer, the deer-like musk being confined to it; it has a peculiar form of wild-dog (*Nyct-*

reutes), and even several peculiar species of the monkey tribe. It is also pre-eminently the home of the pheasant tribe, such magnificent birds as the golden, silver, and Reeve's pheasants being peculiar to it. It has also a number of showy jays, finches, tits, and warblers; and its insects present a number of fine tropical-looking species. The Manchurian sub-region has thus a very beautiful and varied fauna, but the intermingling of Oriental types, and the uncertainty of its southern boundary, render it less characteristically Palearctic than the European sub-regions.

The Ethiopian Region.—This region is much less extensive than the last, but being almost wholly tropical, it presents a richer and more varied assemblage of animals. Its southern extremity, although really extra-tropical, is yet so warm and so little subject to extremes of temperature that the growth of vegetation and the corresponding development of animal life are scarcely diminished, and the same may be said of the elevated interior of the continent. As Madagascar is quite isolated and its productions very peculiar, it will be best first to sketch the main features of African zoology, which are tolerably well marked and homogeneous.

The African continent is pre-eminently the country of large Mammalia. It possesses an abundance of elephants, rhinoceroses of several species, giraffes (now peculiar to it), gorillas and baboons—the largest of the ape tribe, a host of large and remarkable antelopes, the huge hippopotamus, several species of zebras, wild buffaloes, several remarkable forms of swine, and an abundance of lions, leopards, and hyænas,—forming together an assemblage of large and highly organized animals such as occur nowhere else upon the globe. There are also many smaller, but very remarkable forms. There are 7 peculiar genera of apes, 3 of lemurs, 5 of *Insectivora*, 12 of *Viverridæ*, one remarkable *Proteles* forming a distinct family allied to hyænas and weasels, 2 of *Canidæ*, 2 of *Mustelidæ*, 2 of *Suidæ*, 1 of *Tragulidæ*, 12 of *Bovidæ* (antelopes), 18 of

various families of Rodents, and the curious aardvark (*Orycteropus*), forming a distinct family of *Edentata*.

In birds Africa is not so peculiar, yet it has many remarkable groups. Such are the plantain-eaters (*Musophagidae*), the colies (*Coliidae*), the secretary-birds (*Serpentariidae*), the ground horn-bills, and the guinea-fowl,—all of which are peculiar. It abounds also in peculiar fly-catchers, shrikes, sun-birds, weaver-birds, starlings, larks, barbets, grouse, and hawks,—more than half the genera of land-birds being peculiar, and, if we include those of Madagascar, nearly two-thirds.

Reptiles abound, there being three peculiar families of snakes and one of lizards, and there is one peculiar family of toads. There are also three peculiar families of fresh-water fishes.

It is impossible to give any idea of the special features presented by the insects and land-shells without going into details which would be out of place in such a sketch as we are here giving. In both these groups Africa is fully as rich as the other tropical regions, and exhibits perhaps more peculiar features than among the higher animals.

We must, however, just mention the remarkable absence from the Ethiopian region of certain groups of Mammalia which abound in the countries to the north and east of it, as this phenomenon has an important bearing on the probable origin of the fauna. The most striking of these deficiencies are the two families of the deer and the bears, which abound over the whole northern hemisphere, in tropical Asia and the Malay islands, and even in North Africa, but are both entirely unknown over the whole Ethiopian region, as are, among smaller groups, the goats and sheep, the true oxen, and the mole family. Among birds such wide-spread groups as the wrens (*Troglodytidae*), dippers (*Cinclidae*), and the true pheasants are also entirely wanting.

The exceeding specialty of the

forms of life which are still found in the Ethiopian region is well shown by the fact that there are about 24 family groups of vertebrate animals which are entirely confined to it, while two-thirds of its genera of Mammalia, and three-fifths of the genera of birds, are also peculiar.

Subdivisions of the Ethiopian Region.

—The most remarkable of these is undoubtedly that comprising Madagascar and the Mascarene islands, a district which contains so many singular forms of life that it has been proposed by some naturalists to make it one of the primary zoological regions. The peculiarity of these islands is twofold, consisting as much in the absence of a great number of the most characteristic African forms as in the possession of others entirely peculiar. The apes and monkeys, the large Carnivora, the zebras, giraffes, antelopes, elephants, and rhinoceroses, and even such smaller forms as the porcupines and squirrels, are entirely wanting. Yet Madagascar possesses a host of remarkable *Lemuridae*, consisting of 7 genera and 35 species, all of which are peculiar; a peculiar family of *Insectivora*, comprising 5 genera and 10 species; a peculiar family and 5 peculiar genera of small *Carnivora*; and 3 peculiar genera of *Muridae*. Even among birds, so much better able to traverse a narrow sea, there are some curious deficiencies, the families of woodpeckers (*Picidae*), honey-guides (*Indicatoridae*), barbets (*Megalemidae*), plantain-eaters (*Musophagidae*), colies (*Coliidae*), hornbills (*Bucerotidae*), and mockers (*Irisesoridae*)—all abundant on the opposite coast of Africa—being entirely wanting. Yet birds are sufficiently abundant, nearly 120 species of true land-birds being known, while there are no less than 33 genera which are altogether confined to Madagascar and the Mascarene islands. If we consider the species, the peculiarity is even more remarkable, there being more than a hundred which are peculiar to about a dozen which are found elsewhere. These numbers, however, by no means fairly represent the special character of the Mascarene bird-fauna, which consists in the anomalous character of many of the genera, so that it is to this day a matter of dispute among ornithologists in what families a considerable number of them should be classed. Among these anomalous genera are *Mesites*, *Tylas*, *Artamia*, *Calicalicus*, *Euryceros*, *Philepitta*, *Lep-*

tosomus, *Atelornis*, and several others. Taking all these facts into consideration, we arrive at the conclusion that the fauna of Madagascar is more peculiar than that of any other single island on the globe.

The reptiles of Madagascar are less known, but they exhibit some remarkable peculiarities. Many African groups are wanting, others are represented by peculiar genera, while a considerable number of groups have their nearest allies, not in Africa, but in tropical Asia and in South America. Among insects the butterflies are allied to those of Africa; but the beetles, like the reptiles, show many cases of affinity with the Malay islands and South America, though the majority are perhaps related to true Ethiopian forms.

The continental part of the Ethiopian region appears to have no subdivisions clearly marked out by natural barriers, yet it may be divided into three tolerably well-defined sub-regions in accordance with differences of climate and vegetation. These may be termed the sub-region of open plains, the forest sub-region, and the south temperate sub-region.

The first comprises the greater part of Central and East Africa, and a northern belt from Senegambia through Lake Chad to Abyssinia while it extends to the Atlantic coast from Angola to Damara Land. This extensive district may doubtless be further subdivided, but it exhibits throughout the main features of Central African zoology as distinct from that of West and South Africa. Its zoological characters are negative rather than positive, as it has very few peculiar groups; but all the great African Mammalia abound, and a greater variety of antelopes are found here than in the other sub-regions.

The West African or forest sub-region extends from the Gambia to the Congo, and inland to the sources of the Nile and the western watershed of the great lakes. It is characterized generally by a luxuriant forest-vegetation, and it possesses many peculiar animal forms. Here we find the gorilla and chimpanzee, a great variety of monkeys, and two peculiar genera of lemurs, as well as some remarkable genera of *Insectivora*, *Viverridæ*, and *Tragulidæ*. It is the home of the gray parrots (*Psittacus*), the typical plantain-eaters (*Musophaga*), one of the Eastern group of ground thrushes (*Pitta*), and many peculiar genera of passerine birds. Reptiles are very abundant,

no less than 13 genera of snakes and 3 of lizards being peculiar to this sub-region. As is always the case in tropical forest-districts, insects are especially numerous, of large size and brilliant colors.

The South African or extra-tropical sub-region, though quite open to the central districts and to a large extent overrun with the same fauna, yet presents so many peculiarities as to indicate, probably, a former southward extension of the continent. We find here 3 peculiar genera of *Viverridæ*, the remarkable *Proteles*, peculiar *Canidæ* and *Mustelidæ*, many peculiar rodents, including *Bathylarges* (one of the mole-rats), *Petronomys* (one of the spiny-rats), and *Pedetes* (the Cape-hare). There are also some peculiar genera of birds, among which are a sun-bird, 2 weaver-birds, 3 larks, and a curious woodpecker (*Geocolaptes*). Reptiles are still more peculiar, 4 genera of snakes and 10 of lizards being almost or quite restricted to this limited district. Insects, too, are very remarkable, there being 7 peculiar genera of butterflies, and a host of beetles which are either quite peculiar or have their nearest allies in Madagascar, in India, or America. This remarkable and isolated fauna must be considered, in connection with the wonderful Cape flora—so much richer and more isolated than that of any other part of Africa—as indicating important changes in the past history of this part of the globe.

The Oriental Region.—The Oriental region is wholly tropical, but is of smaller extent than the Ethiopian. It is very largely covered with forest-vegetation, and is much broken up into islands and promontories, conditions so favorable to animal life as fully to compensate for its smaller area.

In the larger Mammalia there are many resemblances between the Oriental and Ethiopian regions. Both have anthropoid apes, elephants, rhinoceroses, large felines, buffaloes, and an abundance of civets. But the Oriental region abounds in deer and bears, it has many remarkable *Insectivora*, the Malay tapir, and many wild cattle. It has also a great number of characteristic forms of life. It has 6 peculiar genera of apes, and 3 of lemurs; 5 of *Insectivora*,

among which are two peculiar families, *Galcopithecidae* and *Tupaiaidae*; 12 of *Viverridae*; 1 of *Canidae*; 5 of *Mustelidae*; 2 of *Ursidae*; 1 of *Tragulidae*; 1 of *Cervidae*; 4 of *Bovidae*; and 5 of Rodents.

The birds of this region are exceedingly abundant, varied, and remarkable. Among them are 3 peculiar families of passerine birds—the hill-tits (*Liotrichidae*), the green bulbuls (*Phyllornithidae*), and the gapers (*Eurylamidae*); while the babblers (*Timaliidae*), the fruit-thrushes (*Pycnonotidae*), and the king-crows (*Dicruridae*) are far more abundant than in the adjacent regions. Tits, flycatchers, crows, sun-birds, starlings, kingfishers, pigeons and pheasants are also very abundant, and are represented by many remarkable forms. More than 340 genera of land-birds inhabit the region, of which number 165 are peculiar to it. Reptiles are very abundant. Three small families of snakes are peculiar, and there are a large number of peculiar genera both of snakes and lizards.

Insects are exceedingly varied and beautiful, especially in the Himalayas and in the Malay islands. Among butterflies the *Danaidae* are very abundant, while the true *Papilio*s are perhaps finer than in any other part of the world. Among beetles the *Lucanidae*, *Cetoniidae*, and *Buprestidae* are especially remarkable, while the elegant Longicorns have their full quota of curious and beautiful forms.

Subdivisions of the Oriental Region.—These are tolerably well marked, though very unequal in extent and productiveness. The Himalayan slopes with all the Indo-Chinese countries form the chief and most typical part of the region. Here are the greatest variety of Mammalia and birds, and almost all the more important groups are represented. Three genera of Mammalia and 44 of birds are peculiar to this sub-region.

The Malay Peninsula, with the larger Malay islands, as far as Java, Borneo, and the Philippines, form a sub-region which has much in common with the last, and is almost equally rich, and in some groups even richer and more pecu-

liar. Thus it has no less than 14 genera of Mammalia and more than 40 genera of birds which are wholly peculiar to it, among which are such interesting forms as the orang-utans (*Simia*), the specter-lemur (*Tarsius*), the flying-lemur (*Galcopithecus*) the feather-tailed tupia (*Ptilocercus*), the sun-bear (*Helarctos*), and the magnificent argus-pheasants (*Argusianus*). About an equal number of genera are common to the Malayan and the Indo-Chinese sub-regions, but are not found elsewhere; so that the two have much in common, and together comprise nearly all that is most remarkable and beautiful of the Oriental fauna.

The other two sub-regions consist of the peninsula of India and Ceylon, whose chief feature is their comparative zoological poverty. Taking first what may be termed the Indian sub-region, extending from the foot of the Himalayas to the Carnatic, we find that this extensive and fertile region, though abounding in life of every kind, yet possesses no peculiar genus of either Mammalia or birds; while, favored by the open and arid plains of which much of the surface consists, some African types are more abundant than in other parts of the region, though these are numerically unimportant.

Ceylon and Southern India are somewhat more interesting, as they possess some peculiar forms, and others in common with the Malay islands. Among the former is *Loris*, a peculiar lemur; and there is a peculiar genus of *Muridae*, as well as one or two peculiar genera of birds. There are also several peculiar species of monkeys, and the Malayan genus *Tupaia*; while among birds we find Malayan forms of cuckoos and *Timaliidae*. The reptiles, however, best characterize this sub-region, as it possesses an entirely peculiar family of snakes (*Uropeltidae*), consisting of 5 genera and 18 species, as well as 4 other peculiar genera of snakes. There are also many peculiar genera of lizards belonging to the *Agamidae* and *Acontiade*, and 3 peculiar genera of tailless Batrachia. The insects also offer some remarkable cases of Malayan affinity, the genus *Hestia* (or specter butterflies) being found in Ceylon only beyond the Malay islands; while 6 genera of Malayan Longicorns and the wingless *Tricondyla* belonging to the *Cicindelidae*, are in the same category. The combination of so many peculiarities justifies the separation of Ceylon and a portion of Southern India as a distinct Oriental sub-region.

The Australian Region.—On entering this region we meet with such a radical change in all the higher forms of life that the zoologist seems to have got into a new world. Even the Austro-Malay islands, though differing in no way in climate or luxuriance of vegetation from the Indo-Malay islands to the west of them, exhibits this change in an almost equally marked degree. With the exception of Celebes, which is a debatable land hardly belonging to either region, the other islands only possess a few deer and pigs to represent the host of varied Mammalia—from the elephant and tapir to the squirrel and monkey—which characterize every part of the Oriental region to its extreme south-eastern limits in Java and Borneo. In place of these we have Marsupials only, in great variety in the extensive country of Australia and less abundantly in the islands; and besides these, only those flying mammals—the bats, which can traverse the ocean, and the smallest forms of rodents, the mice—which may be occasionally carried by floating trees or other accidental means across narrow arms of the sea. There are 5 distinct families and 33 genera of Australian Marsupials, as well as 2 families and genera of the still more lowly-organized Monotremata which comprise the anomalous *Ornithorhynchus* and *Echidna*.

Birds, as might be expected, are not so excessively peculiar, a large number of almost cosmopolitan families extending into Australia; yet there are no less than 16 families altogether characteristic of the region among which are such remarkable forms as the Paradise-birds (*Paradisæide*), the honey-suckers (*Meliphagida*), the lyre-birds (*Menurida*), the cockatoos (*Cacatuide*), the lorries (*Trichoglosside*), the mound-builders (*Megapodiide*), and the casowaries (*Casuariide*). Among the important groups which are entirely wanting in Australia are the barbets (*Megalæmide*), the woodpeckers (*Picide*), otherwise cosmopolitan, the

trogons (*Trogonide*), and the pheasants (*Phasianide*). The reptiles, as in most other cases, offer less marked peculiarities than the birds; but a large proportion of the genera are peculiar, and there are even 3 peculiar families of lizards, as well as the singular *Hatteria* of New Zealand, which constitutes not only a separate family but a new order of reptiles. The Amphibia and fresh-water fishes present a corresponding amount of peculiarity; and the recent discovery of the genus *Ceratodus* (the mud-fish) is very interesting, since its nearest allies appear to have lived early in the Secondary period, while other members of the same group are found isolated in the rivers of tropical Africa and America.

Insects are very abundant in Australia and Austro-Malay islands; but owing to the various means by which these small creatures are conveyed across the seas, and the identity of physical conditions in the Oriental and Australian portions of the Archipelago, the true Australian fauna is chiefly developed in Australia itself, where there are a considerable number of peculiar genera in all orders of insects.

Subdivisions of the Australian Region.

—Besides the Australian continent, which is by far the richest and most important part of the region, there are three groups of islands which have each some distinctive peculiarities. These are the Austro-Malay islands, comprising New Guinea, the Moluccas, and the Timor group; the Pacific islands; and the New Zealand group. The first is very rich, especially in birds and insects, while the other two are exceedingly poor.

The Austro-Malayan sub-region, of which New Guinea is the central mass, is comparatively poor in Mammalia, only 9 genera of marsupials being yet known, 6 of them being peculiar, with pigs, a few mice, and some deer (perhaps introduced) in the Moluccas. Birds are far more numerous, the Paradise birds and the true crimson lorries being peculiar to the sub-region, while more than 40 genera of land-birds are confined to it. It is exceptionally rich in peculiar forms of flycatchers, honey-suckers, kingfishers, cockatoos, and

pigeons; and its birds are generally characterized by a brilliancy of plumage far exceeding that which prevails in the surrounding regions. The insects exhibit a similar brilliancy, some of the finest butterflies and beetles in the world belonging to this sub-region.

Directly we pass east of the Solomon Islands we enter upon one of the poorest zoological regions in the world in proportion to its extent and luxuriant vegetation, the only exception to this poverty being in the land-shells, which are very largely developed and very peculiar. Indigenous Mammalia are wholly wanting. Birds are very scarce, no more than about 150 species being known from the numerous islands scattered over 5000 miles of the Pacific, while there are only about a dozen peculiar genera. Reptiles are more numerous than might be expected, considering the wide extent of ocean separating many of the islands. There are 14 genera of lizards, of which 6 are peculiar, but few extend eastward of the Samoa Islands. Snakes are much less abundant, and none are found east of the Fiji Islands. Insects are exceedingly scarce, and of little interest.

The New Zealand group, though situated beyond the tropics and very remote from other lands, yet possesses a more ample and more interesting fauna. If we except two bats, mammals are wanting; but birds are tolerably abundant, and are very peculiar and interesting. There are 34 genera of land-birds, of which 16 are peculiar. Twelve of these are passerine birds, chiefly *Meliphagide* and *Sturnide*, with *Nestor* and *Stringops*, peculiar genera of parrots, and the extraordinary wingless *Apteryx*. Reptiles are few. There are a few lizards, with one peculiar genus, but no snakes. The anomalous *Hatteria* has been already mentioned. There is also one frog belonging to a peculiar genus. There are some interesting fresh-water fishes, one genus belonging to the *Salmonide*, a family not occurring elsewhere in the southern hemisphere; and there are several species allied to South American fishes.

Insects are very few, and generally of small size and inconspicuous colors. Many of them are peculiar, but they have mostly affinities with Australian groups, or with those from the Oriental region.

The Neotropical Region.—This is in some respects the richest zoological region on the globe, yet it has certain resemblances to the Australian region,

which is the poorest, and which it follows in natural order. This is owing to both being inhabited mainly by low types of Mammalia and birds, some of which have been preserved from early geological times, the Marsupials being a good example. But there has also been some intermigration between south temperate America and Australia, by means of intermediate islands and floating ice, and this has led to a community of forms in a few groups to which such a mode of transmission was possible.

The Mammalia are as abundant and varied as in any other countries except Africa and tropical Asia; but the region is characterized by poverty in the more highly organized forms, with a corresponding abundance of lower types. Monkeys are abundant, but all belong to two peculiar families—*Cebide* and *Hapalide*—different in structure and of a somewhat lower organization than those of the Old World. About half of them have powerfully prehensile tails, a character unknown among the monkeys of the eastern hemisphere. Bats are very numerous, and one extensive family—the *Phyllostomide*, or vampyre-bat—is peculiar. Insectivora are unknown in South America, but one peculiar genus occurs in the larger Antilles, and a few shrews in Central America. The Carnivora are but moderately numerous, the *Civet* family being entirely wanting, as are the bears, with the exception of a solitary species in Chili. There is, however, one peculiar family—the *Procyonide*—which extends over North America as well. A marked feature is the excessive scarcity of the great family of the Ungulata, or hoofed animals. There are no wild cattle, sheep, goats, antelopes, horses, or rhinoceroses; and only a very few species of tapirs, peccaries, llamas, and deer in their place. Coming to the small and feeble Rodents, however, we find a great abundance and variety of forms, including the largest on the globe. Five families are peculiar or nearly so,—the chinchillas and the cavies being the most important, while

all the genera, except *Sciurus* and *Lepus*, are peculiar to the American continent. We now come to the Edentata, the most imperfectly organized and the most characteristic of the Neotropical mammals. There are twelve genera belonging to the three families of the sloths (*Bradypodidae*), the armadillos (*Dasypodidae*), and the ant-eaters (*Myrmecophagidae*). Lastly, we have the marsupial opossums, which range far over temperate North America, but are most abundant in the tropical regions of South America.

In birds the Neotropical region is wonderfully rich. It possesses far more distinct genera and species than any other region, and it has 24 entire families peculiar to it, while the region which comes next in specialty and isolation as regards this order—the Australian—has only 16. Most of these peculiar families are, however, of a somewhat low grade of organization, and it is these which abound most in genera and species and give a special feature to the ornithology of the country. These peculiarly American families (for some of them range into North America) are the tyrant flycatchers (*Tyrannidae*), the manakins (*Pipridae*), the chatterers (*Cotingidae*), the plant-cutters (*Phytotomidae*), the tree-creepers (*Dendrocolaptidae*), the ant-thrushes (*Formicariidae*), and the wren-thrushes (*Pteroptochidae*). All these have a deficiency in the singing muscles of the throat, and they comprise more than 200 genera. Then, among the *Picariae*, which are a low though wide-spread order, we have the toucans (*Rhamphastidae*), the puff-birds (*Bucconidae*), the jacamars (*Galbulidae*), the motmots (*Momotidae*), and the humming-birds (*Trochilidae*), comprising 140 genera. The only peculiar families of high organization are the sugar-birds (*Cærebidae*), the greenlets (*Vireonidae*), the hang-nests (*Icteridae*), and the tanagers (*Tanagridae*), comprising in all 82 genera. The most highly organized groups of birds, and those which are most abundant in the eastern hemisphere, such as crows, starlings, thrushes,

warblers, and flycatchers, are either scarce or entirely wanting. Finches are numerous, as are parrots. Among game-birds the higher types, as the grouse (*Tetraonidae*), are scarce; while the more lowly-organized curassows (*Cracidae*), and tinamous (*Tinamidae*) are much more abundant and more widely distributed over the whole region. Among the wading groups (*Grallae*), which are decidedly of low organization, there are 6 peculiar and very isolated families, the most remarkable being the *Cariamidae*, the *Psophiidae* (trumpeters), the *Eurypygidae* (sun-bitterns), and the *Palamedeidae* (horned screamers). The very low struthious type is represented by the American ostriches (*Rhea*).

Reptiles are also very abundant in the Neotropical region, and there are many peculiar groups. Snakes are represented by peculiar genera only, the families being almost always widely and often universally distributed in warm regions; lizards are more restricted in their range, and no less than 5 families are peculiar to the region, while 9 are found only in the American continent. All are of very small extent except two, the *Tevide* and *Iguanidae*, which are very numerous, and comprise the most characteristic American lizards. There are also 4 peculiar families of tailless Batrachians, the most popularly known being the *Pipidae*, which contains the remarkable Surinam toad.

Fresh-water fishes are probably more abundant and varied than in any other region. Three entire families and several sub-family groups are peculiar, and the enormous forest-bordered rivers and extensive tracts of annually flooded woodland have led to the development of special groups of fruit-eating fishes, which, as articles of food, are not only unsurpassed but altogether unequalled in any other part of the globe. Fresh-water rays (*Trygonidae*) and electric eels (*Gymnotidae*) are also peculiar to Neotropical rivers, and there are an immense variety of *Siluridae*, *Characinidae*, and *Cyprinodontidae*. It is reported that Professor

Agassiz obtained more than a thousand species of fishes in the Amazon alone; but, although this may be exaggeration, there is no doubt that a still greater number exists in that wonderful river and its tributaries.

The insects of tropical America are so inexhaustible in their variety, and so wonderful in their beauty, that it is hopeless to attempt to give an adequate idea of them. The butterflies are far more abundant and more gorgeous than in any other region, and their variety may be imagined from the fact that the peculiar genera are nearly equal in number to those of the rest of the world. The beetles, though very abundant, are not so clearly preponderant over those of all other regions. The stag-beetles (*Lucanidae*) and rose-chafers (*Cetoniidae*) are somewhat poorly developed; but all the other large families are very abundant, and comprise many forms of extreme beauty and interest. Such are the genera *Agra* among Carabidae, *Pyrodes* among Longicorns, and *Entimus* among Curculionidae. Land-shells equally surpass those of all other regions, but this is owing to the exceptional richness of the West Indian islands, the continent of America being by no means extraordinarily rich in this class of animals.

Subdivisions of the Neotropical Region.—The manner in which this region may be most naturally and conveniently divided for zoological purposes is doubtful. Almost the whole of tropical South America (excluding only the higher Andes south of Chimborazo and the dry plain to the west) forms a compact area in which all the more characteristic Neotropical animal groups are developed in their highest luxuriance. This, however, falls naturally into three subdivisions, which may be generally indicated as Guiana, Brazil, and the Eastern Andes, each of which is characterized by a great number of peculiar generic types. These three areas are considered by Professor Newton to be sub-regions, each equivalent to the whole of south temperate America, and to the tropical part of North America, which may be termed the Mexican sub-region. But each of these latter may be also divided. South temperate America

consists of a western and an eastern division, each with many distinct groups, while the southern parts of Central America differ greatly from the northern; and all these subdivisions may be considered as provinces of their respective sub-regions. It seems better, therefore, for the purposes of such a general sketch as the present, to consider the tropical parts of South America, as above limited, to be one great sub-region, characterized by possessing a large proportion of the animal forms of the whole region. It will therefore only be necessary to indicate in what way the other sub-regions differ from this.

The Chilian sub-region, or temperate South America as above defined, is well characterized by its exclusive possession of the family of the *Chinchillidae* (comprising three genera) and the genus *Auchenia* (the llamas and alpacas), the only representatives of the *Camelidae* in the New World. It also has a peculiar form of bear, several peculiar genera of rodents, and two peculiar forms of armadillos. Among birds it has the curious plant-cutters (*Phytotomidae*), a peculiar family of waders (*Thinocoridae*), about 26 peculiar genera of passerine birds—1 of parrots, 2 of pigeons, and 2 of tinamous. It also possesses the American ostriches (*Rhea*), and three peculiar genera of plovers. The reptiles are usually of tropical genera, but a few are peculiar. Many of the fresh-water fishes are of peculiar genera, but there are some Australian forms, and even one species (*Galaxias attenuatus*) is common to New Zealand, Tasmania, and Patagonia.

Among insects alone we meet with indications of a decided affinity for forms of the north temperate zone. There are several butterflies allied to *Erebia*, an Arctic genus, and others belonging to the northern genera, *Hipparchia*, *Argynnis*, and *Colias*. The mass of the butterflies, however, are purely Neotropical. Of the beetles some are Australian, but the majority are allied to Neotropical forms; yet among the *Carabidae*, or carnivorous ground-beetles, there are many truly northern genera, such as *Carabus*, *Anchomenus*, *Trechus*, etc., whose presence supports the theory of a migration along the Andes from the northern hemisphere. (See Wallace's *Geographical Distribution of Animals*, vol. ii. pp. 44-48.)

In tropical North America, or the Mexican sub-region, we find far less peculiarity. The southern portion from Panama to Nicaragua can hardly be separated zoologically from the adjacent parts of

South America, while further north the chief difference consists in the absence of many typical Neotropical groups, and the appearance of a few which more especially characterize the Nearctic region. A peculiar form of tapir (*Elasmognathus*) inhabits Central America, with one or two peculiar genera of rodents; while such northern forms as *Sorex*, *Vulpes*, *Lepus*, and *Pteromys* range as far south as Guatemala. Birds are more especially characteristic, since the sub-region possesses no less than 37 peculiar genera of land-birds; but many Neotropical groups are absent. The most important of these deficiencies are the *Pteroptochidae*, and the sub-families *Furnariinae*, *Conopophaginae*, and *Rupicolinae*, as well as most of the peculiar groups of waders. In place of these are found tits (*Paridae*), creepers (*Certhiidae*), waxwings (*Ampelidae*), and turkeys (*Phasianidae*) from the north. The fresh-water fishes as well as the insects are almost wholly Neotropical in character, but exhibit a considerable amount of specialty.

There remains the West Indian Islands or the Antillean sub-region, which in the amount of isolation and specialty it exhibits is better marked than any other part of the region. The Mammalia are few but very interesting, as is usually the case in islands separated from continents by very deep sea. There are no monkeys, Carnivora, Ungulates, or Edentata, the only orders represented being the Insectivora and the Rodentia. The former, which is unknown in South America, is here represented by a peculiar genus, *Solenodon*, belonging to a family, *Cen-tetidae*, only found elsewhere in Madagascar. The Rodents consist of two very peculiar genera—*Capromys* and *Plagiodontia*, belonging to a family which is especially South American, with a peculiar mouse, and an agouti (*Dasyprocta*) in the lesser Antilles. The birds are far more abundant, about 200 resident species being known, besides a large number of migrants from the United States. These belong to 95 genera, of which about one-third are peculiar. The only entirely peculiar family group is that of the todies (*Todidae*), small and elegant birds whose nearest allies are the South American motmots and jacamars.

The reptiles are not very well known, but they seem tolerably numerous, and mostly allied to South American groups; and the same remark applies to the fresh-water fishes. Insects are not very abundant, and beetles seem especially scarce

considering the luxuriant vegetation of most of the islands. In land-shells, however, the very reverse is the case, the Antilles being more productive than any other part of the world. The number of species of West Indian land-shells is equal to that of the entire continent of America, while the number of genera is greater. No less than 11 of the genera are peculiar, a very unusual degree of specialty considering the extensive range of most of the genera of land Mollusca.

The Nearctic Region.—This comprises all temperate North America; and its peculiar fauna is best represented in the United States, and especially in that portion extending from the Mississippi valley to the Atlantic. It is allied both to the Neotropical and the Palæarctic regions, but it also possesses a considerable number of peculiar or characteristic forms. Among Mammalia it possesses 3 peculiar genera of moles, 2 of weasels, 2 of hollow-horned ruminants—*Antilocapra* (the prong-buck) and *Aplocerus* (the mountain goat or antelope)—and a number of Rodents, among which the most peculiar are the *Sacomys* or pouched-rats. Of those groups which are more peculiarly Neotropical it has skunks (*Mephitis*) raccoons (*Procyon*), and opossums (*Didelphys*). The number of Palæarctic groups is greater, the more important being lynxes, wolves, martens, bears, elks, bison, sheep, flying-squirrels, and marmots.

Of birds there are between forty and fifty genera which are peculiar or highly characteristic. Most of them belong to the passerine families, the wood-warblers (*Mniotiltidae*) and the finches (*Fringillidae*) being especially rich in peculiar groups; and there are also a few among the thrushes, wrens, crows, hang-nests, woodpeckers, grouse, and some other families. Among the larger birds the turkeys (*Meleagris*), the ruffed grouse (*Cupidonina*, etc.), and the crested partridges (*Oreortyx*, etc.), are the most remarkable.

Reptiles seem to be more numerous than in the Palæarctic region.

About a dozen genera of snakes are peculiar or characteristic, the most remarkable being the well-known rattlesnakes (*Crotalus*). Among lizards the so-called "glass-snake" (*Ophisaurus*) is a peculiar form analogous to our slow-worm; while the horned-lizards (*Phrynosoma*) and many other genera of Iguanidæ are peculiar. Fresh-water fishes are exceedingly numerous and highly peculiar, there being no less than five (or, according to recent authors, eight) peculiar families, and a large number of peculiar genera. The perches and their allies (*Percidæ*, *Ichthelidæ*, *Labracidæ*, and *Etheostomidæ*), the carps (*Cyprinidæ*), the suckers (*Catostomidæ*), and the catfish (*Siluridæ*) are the most abundant groups.

In insects the Nearctic region is not remarkably rich or very peculiar. Its butterflies, though tolerably abundant, belong for the most part to well known European groups with a small infusion of Neotropical forms in the Southern States. The same may be said of its Coleoptera. Land-shells are tolerably plentiful, but not strikingly peculiar; the Alleghany district being the most productive, and possessing a large number of peculiar species. In fresh-water shells North America surpasses every other part of the globe, considerably over a thousand species, most of them *Unionidæ*, or fresh-water mussels, having been described.

Subdivisions of the Nearctic Region.

—Owing to the researches of American zoologists these have been ascertained with tolerable accuracy, and may be termed respectively the Californian, the Rocky Mountain, the Alleghany, and the Canadian sub-regions.

The western or Californian sub-region comprises the narrow tract between the Sierra Nevada and the Pacific, not including Lower California, but extending northward into British Columbia to about 53° N. lat. It is characterized by a few very peculiar forms, and by a greater infusion of South American types than are found in similar latitudes on the east coast. Among mammals *Macrotus*, a genus of vampyre bats; among birds a cuckoo of the genus *Geococcyx*, and .2

genera of humming-birds (*Selasphorus* and *Atthis*); and among reptiles *Lichanotus*, a snake allied to the boas, are Neotropical forms. California has also five or six peculiar genera of Mammalia,—*Urotrichus*, one of the moles, and *Haplodon*, forming a distinct family of Rodents, being the most remarkable; while *Chamaea*, forming a distinct family allied to the wrens, is the most interesting and peculiar bird.

The central or Rocky Mountain sub-region extends eastward from the Sierra Nevada across the Rocky Mountains to a line a little eastward of the 100th meridian, where a marked change in the climate, vegetation, and animal life is found to occur. To the north it is bounded by the great Canadian forest-zone on the upper Saskatchewan, while southwards it extends into Texas and Lower California and along the line of highlands to beyond the city of Mexico. This sub-region is characterized by many peculiar animals, some of which are closely allied to Palæarctic types—as the so-called buffalo (*Bison americanus*), the big-horned sheep (*Ovis montana*), the glutton (*Gulo arcticus*), and the pika (*Lagomys princeps*); while others are altogether distinct forms, as the prong-horn (*Antilocapra*) and the antelope or mountain goat (*Aplocerus*). Of Palæarctic forms of birds it has two peculiar genera of grouse (*Centrocercus* and *Pediocetes*), and the Arctic wood-pecker and ptarmigan. More especially Nearctic are a genus of wrens (*Salpinctes*) and some peculiar genera of finches and crows. The Nearctic pouched-rats (*Sacomysidæ*) are abundant.

The eastern or Alleghany sub-region comprises the country to the east of the last, and as far north as Wisconsin and the southern parts of Canada. It contains examples of all that is most characteristic in Nearctic zoology, and has besides a few peculiar groups. Of these the most noteworthy is the star-nosed mole (*Condylura*), and among birds the passenger-pigeon (*Ectopistes*) and a few groups of wood-warblers and finches. The reptiles are more peculiar, as there are several genera of snakes, including two of *Homalopsidæ* and two of rattlesnakes, which hardly extend beyond it. Among lizards the glass-snake (*Ophisaurus*) is peculiar, and no less than four genera of tortoises are almost or quite confined to the sub-region. Here, too, are found the peculiar Amphibia for which North America is so remarkable, such as

the two genera of the Sirenidæ (*Siren* and *Pseudobranchius*), *Menobranchius*, allied to the *Proteus* of Europe, *Amphiuma*, an eel-like creature with four rudimentary feet, constituting a distinct family, and three peculiar genera of salamanders (*Salamandriæ*). Fishes, too, are very abundant, and several of the peculiar North American forms are confined to this sub-region; such are the pirate-perch (*Aphredoderus*), the cave-fishes (*Amblyopsidæ*), the trout-perches (*Percopsidæ*), several genera of sun-fishes (*Ichthelidæ*), and many others.

The sub-Arctic or Canadian sub-region has very few distinctive features, but it serves at once to connect and separate the other three regions which almost merge into it. The musk-sheep (*Ovibos*) is almost the only form peculiar to it, though this is more properly Arctic. Many of the most characteristic Nearctic animals, such as *Condylura* and *Mephitis*, only just enter its southern borders, while most of the Arctic forms are more abundant here than farther south. Great numbers of birds migrate here in summer from the Southern States and Mexico; while a few especially Palearctic groups (as *Budytes*, *Phylloscopus*, and *Pyrrhula*), which do not occur elsewhere in North America, have been found in Alaska. The scanty fauna of Greenland shows that it forms a part of this sub-region.

DISTRIBUTION OF THE HIGHER ANIMALS DURING THE TERTIARY PERIOD.

Before we proceed to other divisions of our subject, we shall find it useful to consider briefly the geographical relations of the Tertiary and post-Tertiary faunas to that which now exists, as we shall thereby arrive at a better comprehension of the true nature of zoological regions, and the meaning of the diverse and complex relations that exist between them.

Post-Tertiary Faunas.—Researches in alluvial clays and gravels, cave-earths, and other superficial deposits have made known to us very completely the character of the fauna which immediately preceded that now existing, and which lived at the close of the glacial period and in the era of prehistoric man. We find, as might be expected, that a considerable num-

ber of the Mammalia were identical with living species, but along with these we almost always find a number of extinct forms, some closely related to living species in the same district, while others seem to indicate migration and a change of climate, by their resemblance to species which now only live further north or south. More extraordinary is the fact, that many of these recently extinct forms were of huge size as compared to any now living, often reminding us of the bulkiest inhabitants of the tropics or of those huge animals which we associate with an earlier condition of the earth's surface. Thus, in Europe during the post-Tertiary period, the reindeer, the glutton, and the Tartarian antelope, inhabited France, along with powerful felines allied to the existing lion. At the same time elephants and rhinoceroses of several species roamed all over Europe; and at one period hippopotami ranged as far north as the Thames, while the European beaver was replaced by a much larger species. In North America about the same time we find extinct lions, horses, tapirs, and camels, with bisons and musk-sheep, as well as elephants and mastodons; and along with these, three genera of gigantic sloths as large as rhinoceroses and elephants,—forming an assemblage of large Mammalia wonderfully different from that which now exists in the same country. In South America we find that there were larger monkeys than any now living, together with lions, bears, horses, tapirs, and antelopes, as well as mastodons, and a tree-porcupine as large as a peccary. Here also were armadillos as large as a rhinoceros, and huge sloths as in North America but of more varied kinds. Even in Australia very similar phenomena occur. Extinct wombats as large as tapirs, kangaroos the size of elephants, and a phalanger nearly as large as a lion have been found in cave-deposits, along with a number of other forms more nearly like those now living. But in this case *all* are Marsupials or Monotre-

mes, and there is no sign of any migration from other lands, which indeed, owing to the insular nature of the country, we could hardly expect. Again, in New Zealand and Madagascar we have a similar phenomenon presented to us by the great extinct terrestrial birds—the “moas,” the “dodos,” and the *Epyornis*, which from the conditions under which their remains are found, have evidently not long ceased to exist.

It appears then that in all parts of the world where we have been able to obtain the requisite information, the period which immediately preceded that in which we live was characterized by great movements or migrations of the higher animals where that was possible; and everywhere, by the extinction of a variety of huge animals belonging to almost every order of Mammalia and to several orders of birds, many of which are now totally unrepresented on the globe.

A. Tertiary Faunas, and their Geographical Relations with those of the six Zoological Regions.—When we go back to the late and middle Tertiary deposits, we find a series of remains of the higher animals which exhibit yet more remarkable changes of distribution. Various parts of central and southern Europe, for example, were then inhabited by animals which now form the most characteristic features of Ethiopian and Oriental zoology—such as apes and monkeys, lions, and hyenas, horses, tapirs, elephants, rhinoceroses, giraffes, and various antelopes; and along with these a number of extinct ancestral forms of many of the same groups. Among birds, too, we find the eastern jungle-fowl, the edible-nest swift, and the trogon, along with African parrots and plantain-eaters. In the Miocene beds of Northern India are found such typical African groups as the hippopotamus and giraffe.

Now geology teaches us, that in the Eocene, or earliest portion of the Tertiary epoch, a continuous arm of the sea extended from the Bay of Bengal to the Atlantic Ocean, cutting

off the peninsula of India and Central Africa from the Palæarctic region;* and it is therefore highly probable that, when this sea-bed became dry land, the various large Mammalia now so characteristic of Africa entered it for the first time from the north. This will explain many of the peculiarities of the Palæarctic, Oriental, and Ethiopian regions, and of their several sub-regions, and especially the persistence of low types in those districts which were wholly or partially protected from the competition of more highly organized animals.

The Tertiary fauna of North America compared with that of Europe exhibits proofs of a former communication between the two northern continents both in the North Atlantic and North Pacific, but always, probably, in rather high latitudes. This is indicated both by the groups which appear to have originated in one continent and then to have passed across to the other, and also by the entire absence from America of many important groups which abounded in Europe (and *vice versa*), indicating that the communication between the two hemispheres was always imperfect and of limited duration.

The past zoological history of North and South America exhibits a somewhat analogous series of phenomena. Their productions were generally very dissimilar. North America, in closer connection with the great northern continent, made an almost equal advance in the development of the more highly organized animals; while South America, for the most part isolated and thus prevented from receiving a constant supply of immigrants from the larger land-areas, developed a series of lowly-organized creatures, the smaller forms of which still constitute its chief zoological feature.

The knowledge we possess of Tertiary and post-Tertiary Mammalia

* See Mr. Seales V. Wood, Gun., “On the Form and Distribution of the Land Tracts during the Secondary and Tertiary Periods respectively, and on the effect upon Animal Life which great changes in Geographical Configuration have probably produced” (*Philosophical Magazine*, 1862).

thus gives us an important clue to the successive migrations of the various groups of animals from one region to another, and to the geographical changes which rendered such migrations possible. The general result arrived at is, that the great northern continents represent the original seat of mammalian life, and the region of its highest development; while the southern continents—Australia, South America, and Africa—have been isolated for varying periods, and, after receiving an immigration of lowly forms, have developed and preserved these to a greater or less extent, according as they were more or less completely protected from the irruption and competition of higher types. Australia, during the Secondary period, received from the northern continent a stock of Marsupials and perhaps some still lower forms, and, having been since completely isolated, has developed these groups alone into its existing fauna. South America, at a somewhat later period, obtained the ancestors of its Edentata and Rodents; and though at various times some higher forms entered it from the north, these never seem to have been sufficiently numerous to overcome its indigenous fauna. In Africa the case was different. For a long time its Mammalia were probably analogous to those of South America; but when the great irruption of higher animals took place in the latter part of the Tertiary period, most of these were destroyed, and a few only remain—such as the *Orycteropus*, the Lemurs, and the peculiar rodents—as indications of the character of the primeval fauna. In the peninsula of India a very similar course of events occurred, and the fauna of both these countries now consists mainly of comparatively recent immigrants. (For a fuller discussion of this subject see Wallace's *Geographical Distribution of Animals*, chapters vi. to xv.)

B. The Birth-place and Migrations of some Mammalian Families and Genera.—From the knowledge we now possess of the extinct fauna of most of

the great continents, it is possible to determine approximately the original birth-place of some now widely distributed groups. The true bears, for example, date back in Europe to the older Pliocene, while in North America they occur only in post-Pliocene deposits. We may conclude, therefore, that they originated in the Old World and are comparatively recent immigrants in America. True horses of the genus *Equus* are also of older Pliocene date in Europe and of the post-Pliocene, or perhaps newer Pliocene, in America, and are therefore also recent immigrants into the latter country. But it is a curious fact that the most perfect series of ancestral forms of horses occur in the Miocene and Eocene deposits of North America; whence it would seem probable that the earlier stages of the development of this wonderfully specialized animal were effected in America, whence they passed to the eastern hemisphere, and there attained to the full development of the equine type, again, perhaps, to be transferred to America,—to be largely developed there (for remains of eight or ten distinct species have been discovered), and finally to become wholly extinct, while continuing to exist in the Old World, whence the most perfect form has been again introduced, and seems quite capable of maintaining itself in a wild state. Tapirs, though now more abundant in America than in Asia, are an Old World group, going back to the Lower Miocene in Europe, but only appearing in America in the post-Pliocene epoch. The peccaries (*Dicotyles*), now almost wholly Neotropical, are really a North American group, and probably only entered South America in later Pliocene times. Camels, though now confined to Asia and South America, are really a North American form, having been largely developed during the Miocene period, whence the true camels appear to have passed into Asia and the llamas into South America. True deer are European from Miocene times, but only appear in America in the later Plio-

cene and post-Pliocene epochs. Elephants are an Old World type, abounding from the Miocene period in Europe and Asia, but only appearing in America in the later Pliocene and post-Pliocene times. It is possible, however, that the Eocene *Dinocerata* of North America may be ancestral forms of *Proboscidea*, and that, as in the case of the horses, the development of elephants may have begun in America to be subsequently perfected in the larger area of the eastern hemisphere. As a last and curious example we may refer to the marsupial opossums, now exclusively American, but which are certainly recent immigrants from Europe or Asia. No trace of them occurs in American deposits before the post-Pliocene period, while they existed in Europe both in Eocene and Miocene times.

The cases now adduced are sufficient to show how much interest attaches to the distribution of the ancestral forms of our existing animals; but we wait for fuller knowledge of the Tertiary deposits of Asia, Africa, and South America in order to complete the history of these migrations, and to gain some knowledge as to many other groups whose origin is now involved in obscurity (*Geog. Dist. of Animals*, vol. i. p. 153).

DISTRIBUTION OF MARINE ANIMALS.

The zoological regions which serve to represent the main facts of the distribution of land animals are evidently inapplicable to those inhabiting the ocean, except in a few cases where the group is confined to shallow waters or to estuaries. It is true that, as the great continents are separated by the oceans, so the oceans are to some extent separated by the continents, but owing to the superior area of water the separation is far less complete and effective. In the southern hemisphere the Pacific, Atlantic, and Indian oceans freely communicate, and for truly oceanic animals there would seem to be hardly any obstacle against universal distribution.

Yet even in this case physical conditions, especially depth and temperature, are found to be effective barriers. The fact that the deep waters even of the tropical seas are cold, renders it indeed possible for some temperate or Arctic forms to cross the equator if they can travel at great depths; but for surface-dwellers the broad expanse of warm water between the tropics, with its hosts of specially adapted organisms, forms an absolute barrier. In like manner the inhabitants of the tropical shallow waters are limited, and it is only by temporary subsidences of land or elevations of the sea-bottom to near the surface, allowing of a passage east or west, that they can migrate into remote areas. We have good reason to believe, however, that subsidences have often occurred between North and South America, allowing of a free interchange of aquatic animals between the Atlantic and Pacific oceans; while in Eocene times a strait is supposed to have connected the Atlantic and Indian oceans, and more recently the Red Sea and Mediterranean have almost certainly been united. We cannot, therefore, expect to find any such strongly-marked zoological regions among aquatic as among terrestrial animals, and the facts at our command entirely confirm this view. For many groups the warm and the cold, or the northern, tropical, and southern seas, are the only well-marked divisions; while for others the North Atlantic, the North Pacific, and the Indian Ocean form additional regions of a more or less defined character. For special studies of the more highly-organized marine groups—as the Mollusca or Crustacea—a host of provinces and sub-provinces have been formed, each important sea or coast presenting some peculiar features; but as these divisions mostly depend on specific rather than generic distribution, they need hardly be noticed here.

Owing to the absence of any well-marked regions, and the general imperfection of our knowledge of the

distribution of marine animals, we must follow a different plan in our sketch of this subject from that adopted for the terrestrial fauna. We propose, then, to notice successively the more important classes of marine animals, and to state briefly what general facts are established as to their distribution.

Foraminifera.—These exceedingly low organisms are important, because their shells or tests are found extensively in various geological formations, and often form a considerable part of the constituents of rocks. They are found in all seas, and the species have often an enormous range. The surface swimmers are almost universally distributed, while the bottom-livers—as the writer is informed by Mr. H. B. Brady—appear to be distributed according to depth and latitude rather than to follow any circumscribed areas. This gentleman is now engaged in working out the “Challenger” collections, and already sees reason to think that there may be found some differences between Atlantic and Pacific, and also between North Atlantic and South Atlantic forms. These organisms have been found living in the surface waters and down to a depth of 3000 fathoms, but only their dead remains are brought up from the floor of the deep ocean.

Spongida.—Sponges form another extensive group, often preserved as fossils, of which our knowledge of the recent forms is rapidly increasing. There seems, however, to be little geographical limitation of groups. The fresh-water *Spongiellæ* are found in all regions. The horny and calcareous sponges are widely distributed, but are much more abundant in warm and tropical seas. The beautiful siliceous sponges—of which the glass-rope (*Hyalonema*) and Venus’s flower-basket (*Euplectella*) are conspicuous examples—are found scattered throughout all warm seas, and have recently been found in abundance in many of the great ocean depths,—in the Atlantic at 2650 fathoms, and in

the Pacific at 3000 fathoms,—so that they probably exist wherever the nature of the bottom is favorable. (Sir Wyville Thomson, *Depths of the Sea*; “Reports from the ‘Challenger,’” *Proc. Roy. Soc.*, vol. xxiv.; Bowerbank’s “Papers on Sponges” in *Proceedings of Zoological Society*, 1869–1874.)

Actinozoa.—The coral-bearing groups of these animals are the more important, because of the abundance of fossil forms of every geological age. By far the greater number of these are found exclusively in tropical seas. Many of the *Alcyonaria* are temperate and even Arctic, while among the *Zoantharia* the *Caryophyllidæ* alone are well represented beyond the tropics. The distribution of corals is in great part determined by the physical conditions of the sea-bottom. An influx of fresh water or of mud brought down by rivers is fatal to them, and volcanic deposits seem to be almost equally prejudicial. A high temperature is also necessary for most of the groups. Coral reefs are therefore restricted to certain seas and coasts within or near the tropics. They abound in and near the West Indies, on the east coast of Africa, in the Indian Ocean, in the Malay and Pacific archipelagoes, and on the coast of Australia; while they are absent from the whole of the west coasts of South America and of Africa, from the Indian peninsula, and from much of the east coast of South America. The coral reefs of the Bermudas in 33° N. lat., are the farthest from the equator; in the Red Sea they reach 30° N., in the Pacific 27° N., while they nowhere extend to more than 29° S. of the equator. Besides the corals actually forming the reefs, the same localities abound in what are termed deep-sea corals, and thus the general distribution of the group is determined by similar conditions. The coral regions are therefore somewhat peculiar, and differ considerably from those which best exhibit the distribution of other marine animals. The regions adopted

by Mr. Dana are three,—the first comprising the Red Sea and Indian Ocean; the second, the whole of the Pacific islands and the adjacent coasts of Australia; and the third the West Indies. This last region is the most isolated in position, and it is not surprising that it should contain the largest proportion of peculiar forms. The corals of the Central Pacific are also very peculiar, as are those of the Red and Indian seas. Considering the great similarity of the molluscan fauna of the Pacific and Indian oceans, it is remarkable that the corals should be so different as Mr. Dana's tables show them to be. Although some corals exist at great depths in the ocean, they diminish rapidly when we pass the moderate depth of 200 fathoms. The "Challenger" expedition obtained 27 genera at a greater depth than 250 fathoms, but only 3 of these extended below 1500 fathoms. Count Pourtales on the American coast found them at 400 fathoms; the "Porcupine" expedition first found them at a greater depth than 1000 fathoms in the North Atlantic; while in the Pacific a single species has been found at the enormous depth of 2900 fathoms. The following genera were obtained by the "Challenger" dredgings at a greater depth than 1000 fathoms:—*Caryophyllia*, *Deltocyathus*, *Ceratotrochus*, *Flabellum*, *Amphihelia*, *Cryptohelia* and *Fungia*. Some of these were of brilliant colors—pink, madder-red, white, and emerald-green. A large proportion of fossil genera of coral survive in the deep seas, no less than seven genera, before only known in the fossil state, having been added by the explorations of the "Challenger;" seven of these are found at or below 1000 fathoms. It is curious, however, that the deepest by far of all corals, *Fungia*, is not known to be fossil, nor is any member of the family *Stylasteridae*, six genera of which are deep-sea corals; so that too much importance must not be attached to the fact of genera hitherto only known as fossils having been found living at

great depths in the ocean. (Dana's "Zoophytes" in *U. S. Exploring Expedition*, vol. vii.; "Report on Corals Dredged by the 'Challenger,'" by H. N. Moseley, *Proc. Roy. Soc.*, vol. xxiv. p. 544.)

Polyzoa.—The coral-like Molluscoïda forming the extensive group of marine polyzoa, have been carefully studied, but they are so widely distributed as to offer few special features of distribution. One or two families—as the *Selenariadæ*—are almost exclusively tropical; others—as the *Catenicellidæ* and *Vinculariadæ*—are confined to the southern hemisphere. The *Diastoporidæ* are mostly northern, while the *Celleporidæ* are found in both north and south temperate seas. But the great mass of the families are either universally distributed or widely scattered over the globe. They range to high northern latitudes, having been found abundantly by the Swedish expedition on the shores of Nova Zembla in 70° N. lat. They inhabit the profound depths of the ocean, having been dredged from near 2000 fathoms in the North Atlantic, 2500 fathoms in the Pacific, and 2650 fathoms in the Southern Ocean during the voyage of the "Challenger." (Busk's *Brit. Mus. Catalogue of Marine Polyzoa*; "Challenger" Reports," *Proc. Roy. Society*, vol. xxiv. pp. 466, 468, 572, 635.)

Echinodermata.—The best known groups—the star-fishes and sea-urchins—occur abundantly as fossils, but their existing distribution does not offer many features of special interest. The *Asteroidea*, or star-fishes, are most abundant in the Indian and Pacific oceans, while the *Ophiuroidea* (brittle stars) are better represented in the European and Africa seas. A few genera are exclusively American, but on the whole star-fishes are far less abundant in the western than in the eastern hemisphere. Although most abundant in shallow seas, they also inhabit the floors of the deepest oceans, some having been obtained by the "Chal-

lenger" expedition from a depth of 2700 fathoms in the Pacific. They abound even in the Arctic seas, "hundreds of sea-stars" having been obtained by a single haul of the swab at 76° N. lat. in Novaya Zembla by the Swedish exploring ship "Proven" in 1875. The *Echinoidea* (sea-urchins) are also very abundant in Eastern seas, while they are comparatively scarce in America. Although much larger and more varied in the tropics, they are tolerably abundant in temperate and cold seas; and they probably reach the greatest depths in the ocean, since some have been obtained by the "Challenger" from a depth of nearly 3000 fathoms in the North Pacific. (*Nature*, vol. xii. p. 556; Van der Hoeven, *Handbook of Zoology*.)

Crustacea.—The distribution of the higher Crustacea has been discussed in detail by Mr. James Dana in the *Zoology of the United States Exploring Expedition*; and, considering that most of the species are shore-dwellers, the facts are very interesting and often quite unexpected. We will, therefore, give an abstract of the conclusions of this writer.

The marine regions which best represent the distribution of these animals are three in number, termed by Mr. Dana the Occidental, the Africo-European, and the Oriental. The first comprises both coasts of the American continent; the second, the eastern shores of the Atlantic, both African and European; and the third comprehends the vast area from the east coast of Africa to the Central Pacific. Each of these is of course subdivided into climatal and local provinces, but the primary divisions alone are those which we have now to consider. The facts adduced in support of this scheme of distribution are very interesting. No less than 47 genera are exclusively American, and 15 are common to both the east and west coasts; but as 26 genera are said to be confined to the west coast, and 6 to the east, it will be seen that these two provinces are

really very distinct, even if they do not form primary regions. The Africo-European region has 19 peculiar genera, and only 8 in common with the American region; so that the eastern and western shores of the Atlantic are decidedly more distinct than the eastern and western coasts of America. The extensive Oriental region is by far the richest, containing no less than 115 peculiar genera, and only 19 in common with the Africo-European region. About 40 genera are said to be found in all three regions.

The distribution of Crustacea in relation to temperature also presents some peculiar features. The species are almost equally divided between the tropical and the extra-tropical regions. The highest form of Crustacea—the Brachyura—are most abundant in the tropics, while the less developed Amphipoda and Isopoda are more numerous in temperate and frigid zones. This may, however, in part depend on these groups having been less assiduously collected in the tropics. More interesting, and less open to doubt, is the fact that among the four chief types of Crustacea—Brachyura, Macroura, Isopoda, and Amphipoda—the most highly developed species are extra-tropical. The largest species of the Macroura are found in temperate seas, and though the largest Brachyura are tropical, yet the Maioids—the highest group of Brachyura and of all Crustaceans—reach their largest dimensions in the temperate zone. Mr. Spence Bate adduces the curious fact that in the cosmopolite sub-family *Lysianassina* the largest species are found in Arctic and Antarctic latitudes, while a species from the Straits of Magellan so closely resembles one from Spitzbergen that they may even be identical; and in the family *Caprellidae* the same species often occurs in both the northern and southern hemispheres. Mr. Dana lays great stress on similar cases of wide and discontinuous distribution, which (he considers) necessitate the adoption of the theory of special creations. Thus, two species

(*Kraussia rugulosa*) and *Galene natalensis*) are found at the Hawaiian islands and Natal, but in no intermediate localities. Other identical species occur in the Japan seas and Natal. The same species (*Plagusia tomentosa*) occurs in South Africa, New Zealand, and Valparaiso; and another (*Cancer Edwardsii*) at New Zealand and Valparaiso. The same species and several identical genera (*Latreillia*, *Ephyra*, *Sicyonia*) are found in the Mediterranean Sea and Japan, but in no intermediate districts. Closely allied species (of the genera *Amphiroidea* and *Ozius*) are found in Australia and Chili; but perhaps the most singular fact is the occurrence of closely allied or perhaps identical species of *Palemon* in New Zealand and the British Seas, and also of certain British or American genera (as *Portunas* and *Cancer*) in New Zealand. Many of these cases, and more especially the last, undoubtedly offer great difficulties on the theory of transmission and specific modification. There are, however, some considerations which afford hints for a possible solution of the difficulty. We now know many cases in which the distribution of an animal or a group of animals has been rendered discontinuous by its recent extinction in intermediate localities. The tapirs, for example, exist only in tropical America and the Malay islands, and it might well be argued that no passage from one of these localities to the other is conceivable for such an animal. But we now know that the South American tapir lived in North America down to post-Pliocene times, that in Europe there were tapirs in the later Pliocene period, while in the Pliocene or Miocene period allied species inhabited North India and some parts of China. The present remotely isolated forms are therefore seen to be the remnants of a genus which once ranged over almost the whole northern hemisphere. Perhaps more to the point is the case of the genus *Panopæa*, adduced by Mr. Woodward in his *Manual of the Mollusca*.

There are only 11 living species, which occur widely scattered in the northern seas, the Cape of Good-Hope, Australia, New Zealand, and Patagonia. But of this same genus nearly 150 fossil species are known, distributed over many intermediate localities, so that the existing species are seen to be but relics of an ancient form of life lingering at various points on the outskirts of the vast area it once occupied. Such cases as these occur in all classes of animals where our knowledge of the extinct fauna is sufficiently extensive, and we are therefore justified in believing that a large proportion of the existing instances of anomalous and discontinuous distribution are to be explained in a similar way. In the case of the Crustacea we must also take into account our comparative ignorance of many parts of the globe, and especially our ignorance of the powers of dispersal of the ova, and of the young animals during their earlier larval condition. This dispersal may systematically occur to a far greater extent than we are yet aware of; though only in rare and exceptional instances may a species succeed in maintaining itself beyond the normal limits of its race. The certainty we are now acquiring of the long duration and wide-spread influence of the glacial period must also materially affect such questions as these; for although the equatorial lowlands may never have suffered from its influence, it is highly probable that during the period of greatest cold the temperature of the entire ocean may have been lowered, while in certain directions cold currents may have afforded a passage for temperate forms of marine animals from the northern to the southern hemisphere. While admitting, therefore, that the distribution of Crustacea presents to us some problems of extreme difficulty, we must deny that they are such as to justify, us in resorting to a solution such as "special creation," which is negatived by the evidence afforded by almost every other class of animals.

The reports of the "Challenger" expedition already published afford valuable information on the distribution of Crustacea in the oceanic depths. The higher forms (Decapod) have been found living at a depth of 1875 fathoms in the North Pacific, 2600 fathoms under the equator, and 2385 fathoms in the South Pacific. In the North Atlantic, at a depth of 1900 fathoms, was found a cray-fish allied to the *Astacidae*, but deprived of even the rudiments of eyes, while others equally blind (from both the Atlantic and Pacific) are believed to have their nearest allies among the extinct *Eryonidae* of the Jurassic period. The higher Crustacea, which are most abundant at great depths, and which have afforded the greatest variety of new and interesting forms, belong to the Schizopoda. They have been found at depths of more than 2000 fathoms in the Pacific, and down to 2550 fathoms in the Atlantic Ocean. Some of them are blind, but a more remarkable fact is, that many of them are brightly colored, though living in absolute and perpetual darkness. Among the Edriophthalmata (sessile-eyed Crustacea) example of the remarkable blind family *Munopsidae* have been found at a depth of 2175 fathoms in the Atlantic, and at nearly 2000 fathoms in the Southern Ocean. Other forms usually found in shallow water (*Serolis*) also occurred at great depths—more than 2000 fathoms in the Pacific; and one of these, obtained near the southern ice-barrier at a depth of over 1900 fathoms, was of "a fine blue color with a red spot over the middle of the body." Entomostraca also occur at great depths, the most remarkable being a gigantic Ostracod found at 1600 fathoms in the Southern Ocean. At 1375 fathoms, near the Crozets, a Pycnogonoid (sea-spider) was obtained, measuring 2 feet across the legs. But besides these bottom-dwellers, the trawl nets at different depths showed that the ocean is inhabited by peculiar tribes of free-swimmers—principally Copepoda, Amphipoda,

and Cypridinas, often of a bright orange color. These occurred in all parts of the Pacific to a depth of 2000 fathoms, but they were never found in the surface nets. (*United States Exploring Expedition*, vols. xiii. and xiv.; Spence Bate on "Geographical Distribution," in Spence Bate and Westwood's *British Sessile-Eyed Crustacea*; Dr. Rudolf von Willemödes-Sulim's "Report on the Crustacea of the 'Challenger,'" *Proc. of the Royal Society*, vol. xxiv. p. 585.)

Cirrhipedia.—The barnacles are a tolerably extensive group of anomalous Crustacea, whose distribution differs somewhat from that of the more typical portion of the class. The genera are almost all widely or universally distributed, from 74° 18' N. lat. to Cape Horn, and some of the species have an equally wide range. No genus having more than a single species is confined to the torrid zones, and only two genera are limited to the southern hemisphere. Although the temperate zones have a smaller area than the torrid, they possess rather more species of Cirrhipeds, which Mr. Darwin imputes to the fact of these zones being *two* while the torrid is but *one*. As in some groups of the higher Crustacea, large species are most abundant in the temperate zones. Owing to the wide range of the *genera* the Cirrhipedal regions can only be determined by the distribution of *species*. These, according to Mr. Darwin, are as follows:—1. The North Atlantic, comprising North America and Europe down to N. lat. 30°; 2. The West American, from Behring Straits to Tierra-del-Fuego; 3. The Malayan, from India to New Guinea; 4. The Australian, comprising Australia and New Zealand. The Malayan and Australian regions are the richest in Cirrhipeds. During the voyage of the "Challenger" these animals were found to inhabit the deep seas, the most remarkable being a gigantic *Scalpellum* from a depth of 2850 fathoms in the North Atlantic, while other forms occurred at almost the

same depth in the Pacific. (Darwin's "Monograph of Cirrhipeda," *Ray Society*, 1854.)

Mollusca.—The marine Mollusca, from their great abundance in all seas, the ardor with which they have been collected and studied, and the frequency of their occurrence as fossils, offer an extensive field for the study of distribution. But many causes have combined to render the results yet arrived at unsatisfactory. Their classification has been for some time undergoing a progressive change, owing to the greater attention paid to the organization and development of the animals, but there is still much uncertainty as to the limits of genera and sub-genera. Owing to their being in many cases articles of commerce, either on account of their uses or their beauty, the place where they were originally obtained has often been confused with the place from which they were exported. Their numbers, too, have so rapidly increased that few persons have been found to devote themselves to the great labor of geographical tabulation. And, lastly, the genera are so often of great extent and world-wide distribution that the range of species alone has generally been attended to.

The late Dr. Woodward established a series of eighteen marine provinces, founded professedly on the fact of one-half of the species being peculiar. The distribution of the genera is only casually mentioned, and it is almost certain that a large number of these provinces have no claim to rank as primary regions as regards the distribution of the Molluscan fauna. Mr. Woodward himself states that his Arctic province is comparatively small and exceptional, while the three southern faunas of America, Africa, and Australia differ extremely. All the warmer provinces may, he says, be naturally grouped into three great divisions—the Atlantic, the Indo-Pacific, and the West American; and these are perhaps the only true Molluscan regions. The Indo-Pacific extends from the Red Sea and east

coast of Africa to the easternmost Pacific Islands, and exactly corresponds to Mr. Dana's Oriental region for Crustacea. About 100 species are said to range over nearly the whole of this vast area. The Atlantic region unites the fauna of the east coast of America with that of West Africa and South Europe, but it also has considerable affinity for that of West America, since about 60 genera are common to both. Several important genera appear to be restricted to the north temperate zone, which should perhaps form a distinct region. About 30 important genera are confined to the Indo-Pacific region; and nearly 20 are peculiarly tropical. The Atlantic coasts have few peculiar genera of importance, and the west coast of America hardly any, its difference from the Atlantic fauna on the one side and the Pacific on the other being chiefly specific. There is said to be not a single species common to the east and west coasts of tropical South America; while the corresponding coasts of North America have more than 50 species in common, and many others so closely representative as to be almost equivalent to identical species.

The shells of the Mediterranean were once supposed to be very peculiar, but recent dredgings have proved that most of them exist also in the Atlantic, and it is now doubted if any are really confined to that sea. A small number (about 70 or 80 species) are identical with Red Sea shells. The marine-shells of Australia and New Zealand are exceedingly unlike those of Britain,—exactly the reverse of what obtains among the Crustacea.

The influence of temperature on the distribution of Mollusca is very marked, the warmer regions presenting a greater variety of forms, with a greater proportion of large and finely-colored species. Yet in some cases the largest species are extra-tropical, a striking example being found among the volutes, which abound in tropical seas, yet attain their largest size in New Zealand. In temperate and

even in Arctic seas Mollusca are perhaps as abundant individually as in the tropics, but the number of species and genera is far less, and they are generally dwarfed in size, and of obscure colors.

Till a comparatively recent period very few shells had been obtained at a greater depth than 200 fathoms. These were mostly of small size and obscure colors, belonging to groups of wide range and great geological antiquity. *Dentalium*, *Cryptodon*, *Leda*, and *Arca* were the most important, and it was generally believed that the zero of Molluscan, if not of all but the very lowest forms of life, would be found at a depth of 300 or 400 fathoms. The recent development of deep-sea dredging has, however, completely changed our ideas on this subject, and the Mollusca as well as most other groups of Invertebrata are found to be capable of existing in the profoundest depths of the ocean. Off the coast of Norway Professor Sars has obtained Mollusca from a depth of 450 fathoms; and near Florida, Agassiz found them at 500 fathoms. During the cruise of the "Porcupine" Professor Wyville Thomson obtained species of *Pleurotoma* and *Dentalium* from the enormous depth of 2500 fathoms in the Bay of Biscay. During the recent voyage of the "Challenger" many other groups have been discovered in the deepest seas. In the North Atlantic, 500 miles west of Teneriffe, three small living Mollusca belonging to the genera *Arca*, *Limopsis*, and *Leda* were dredged from a depth of 2740 fathoms; while in the Central Pacific, from a depth of 2425 fathoms, species of *Arca*, *Nacra*, *Pleuronectia*, *Trochus*, *Fusus*, *Dentalium*, and some others have been obtained. All are small, obscurely-colored forms, resembling Arctic rather than tropical shells, due no doubt to the fact that in these profound depths the water is permanently at a temperature very little differing from that of melting ice. Equally interesting is the fact ascertained by the naturalists of the

"Challenger," that the waters of the ocean down to the enormous depth of 1500 fathoms abound with true pelagic Mollusca belonging to the orders Pteropoda, Heteropoda, and Gasteropoda, while below this limit they appear to be absent. (Woodward's *Manual of the Mollusca*; "Challenger" Reports," *Proc. Royal Society*, vol. xxiv. pp. 536, 578; Letters of Sir Wyville Thomson, in *Nature*, vols. 7-10.)

Fishes.—The distribution of marine fishes appears to agree generally with that of the Mollusca and Crustacea, their greater powers of locomotion, leading to a wider dispersal, being to some extent compensated by the more recent origin of most of the species, genera, and families. There are about 80 families of marine fishes, and no less than 50 of these are almost universally distributed. Several other families range over all tropical seas. About 5 families are found only in the Arctic and temperate seas of both hemispheres, while two (*Discoboli* and *Accipenseridae*) are found in the north temperate seas only. The best marked region is undoubtedly (as in the Mollusca and Crustacea) that which extends from the Red Sea and east coast of Africa to the Sandwich Islands and Australia. About ten families are confined to this region (which may be termed the Oriental or Indo-Pacific marine region); many genera of other families equally characterize it, while there are even a number of species which range over the greater part of its vast area. On the other hand, no family of importance seems to be confined to the Atlantic, or to the coasts of Eastern or Western America, the differences of these provinces, as of the European and American shores of the Atlantic, being confined to generic and still more largely to specific forms. Many species of fish have enormous ranges, extending from the North Atlantic to Australia, from the Red Sea to the Sandwich Islands, and from New Zealand to South America. Some

species range over almost the whole Atlantic Ocean, and a considerable proportion of those inhabiting the Atlantic and Pacific coasts of Central America have been found by Dr. Günther to be identical.

It has long been known that a considerable number of fishes inhabit very deep water, never coming to the surface when alive; but the researches of the "Challenger" expedition have added greatly to our knowledge of these curious forms. A large number of genera and species, many of them new, and belonging to ten distinct families, have been obtained in the nets and trawls from a depth of 200 to 2400 fathoms in all the great oceans. These often come up greatly inflated by the expansion of the internal gases; some were transparent, several were blind, and some had curious phosphorescent organs on the head. These deep sea forms generally have a wide range. The greater number of the new and remarkable forms obtained during the voyage of the "Challenger" belong to the *Scopelidae*, a family known to inhabit the deep waters of all the warmer seas. The size attained by marine fishes appears to have no relation to latitude or temperature. (Günther's *British Museum Catalogue of Fishes*; Mr. J. Murray's "Preliminary Report on Vertebrates collected by the 'Challenger,'" *Pro. Roy. Soc.*, vol. xxiv. p. 537.)

Marine Turtles.—These reptiles, forming the family *Cheloniidae*, are too few in number and too widely distributed to afford any indications as to oceanic regions.

Cetacea.—The whales and dolphins form the only group of truly oceanic Mammalia. They are very widely distributed, but their classification is too unsettled, and their history too imperfectly known, to throw much light on the general question of oceanic distribution. Two of the families—*Balenida* and *Balenopteridae*—seem to be confined to the cold and temperate seas of both hemispheres. The *Catodontidae* (compris-

ing the sperm-whales), on the other hand, are more especially tropical and sub-tropical. The *Hyperoodontidae*, or beaked-whales, are widely distributed in northern, southern, and tropical seas; while the largest family—the *Delphinidae*—are universally distributed. The largest whales inhabit the cold northern and southern seas. (Dr. J. E. Gray's *British Museum Catalogue of Whales and Seals*; Mr. Andrew Murray's *Geographical Distribution of the Mammalia*.)

General Relations of Marine with Terrestrial Zoological Regions.—The general facts of distribution of marine animals now adduced accord very well with what we know of those terrestrial changes which have led to the actual distribution of land animals. The great Indo-Pacific region—so well marked in every important group of marine animals—probably owes its individuality to the fact that Australia has been isolated during the whole of the Tertiary, and probably during much of the Mesozoic epoch, while numerous islands in the Indian and Pacific oceans have always afforded an extensive shore-line favorable to the development of aquatic forms of life. The Atlantic has probably been for long periods even more inclosed than it is now, owing to the greater southward extension of South Africa and South America; while the profound depths of its central channel have served as a barrier between the inhabitants of the shallow waters of its eastern and western shores. In like manner the great trough of deep water which separates the most eastern groups of the Pacific islands from the west coast of America has necessarily led to the establishment of distinct oceanic faunas in these regions; while this very fact—the remarkable distinctness of the Pacific and West American faunas—tells us plainly that this barrier of deep ocean is one of the ancient features of the earth's surface.

We shall find, too, that many of the details, and not a few of the

anomalies, of the distribution of marine animals become intelligible from our knowledge of past geographical changes. The considerable affinity between the Crustacea, Mollusca, and fishes of the eastern and western coasts of America exactly corresponds to the fact, clearly established by a consideration of the distribution of living and extinct land animals, that these oceans have been united, at several distinct periods, by two or more channels over what is now Central America, the final union of the two continents being comparatively recent. The fact that the uniting channels were always situated within the same limited area sufficiently explains the considerable amount of generic and specific difference of two faunas ranging over coast-lines running north and south for many thousand miles on the opposite sides of great continents. The curious fact (only recently established) that so deep and extensive an inland sea as the Mediterranean contains but few peculiar marine animals, becomes quite intelligible when we consider that till middle or late Tertiary times it consisted of two inland seas or lakes. Such inland seas are always very poor in animal life; and it is therefore not surprising that the Mediterranean should now contain hardly any forms but such as it has received from the Atlantic, or from the Red Sea during a submergence of the Isthmus of Suez. The numerous allied or even identical forms in the northern and southern oceans, which are not found in the intervening warm regions, are more difficult to explain. Mr. Darwin believes that such facts are due to the action of the glacial period, which at its height may have cooled certain tracts of the tropical ocean sufficiently to allow temperate forms to cross from the northern to the southern hemisphere or the reverse. Perhaps, however, the agency of icebergs may have been sufficient without any permanent cooling of the equatorial ocean; for even now these huge floating glaciers often

reach to 40° N. lat. and 35° S., and, Captain Maury assures us, sometimes even reach the tropics. We may therefore well suppose that during the height of the glacial period icebergs would not only regularly reach the tropics, but, carried on by currents in definite lines, might often pass across the equatorial zone, carrying with them a girdle of cold water in which many inhabitants of the Arctic and Antarctic seas might safely make the passage to another hemisphere. The fact that many forms of plants peculiar to cold or temperate regions are found scattered on isolated mountain summits in the tropics is, as Mr. Darwin has shown, to be explained only by the influence of an extreme glacial period, and this must have produced analogous effects on the inhabitants of the ocean. (*Origin of Species*, HUMBOLDT LIBRARY edition, par. 633.)

DISTRIBUTION OF ANIMALS IN TIME.

The past history of living things as revealed by geology is an ever-changing panorama. At each successive stage some forms disappear, while new ones take their place. The farther we go back the more unlike is the general assemblage of animals and plants to that which now exists. If we confine our attention to any one class or order of animals, we find that it makes its first appearance at some definite epoch, and, under successively changing forms, either continues till the present time, or reaches a maximum, diminishes, and finally disappears. Thus some groups are altogether modern; others extremely ancient; some have run through all their phases in a comparatively short period, others have lived from the earliest epochs of the earth's history of which we have any record, and still survive. If we could be sure that the numerous fossils yet discovered gave us anything like an adequate idea of all the varied forms of life that had ever lived upon the globe and the order in which they had appeared, we should be in a position to decide as

to the truth and value of the development hypothesis. But the more we examine the question, the more certain it becomes that the "geological record," as it is termed, is extremely imperfect, and that the whole of the extinct animals which we have discovered do not form any fair representation of the entire series that have lived upon the earth. This is the case even with the more recent deposits and those which are richest in animal remains; but as we go back into the past the record becomes more and more imperfect, till in the Secondary, and still more in the Palæozoic formations, we only have preserved to us a few scattered fragments, equivalent perhaps to a few pages with here and there a short chapter taken at random out of a voluminous history. The causes of this necessarily imperfect record of the past have been fully discussed by Sir Charles Lyell and Mr. Darwin; we need only refer here to two general causes of such imperfection. The first is, that every aqueous deposit is formed by the wearing down of previous deposits, so that the records of one age are, to a large extent, necessarily destroyed to provide the records of the next, which in its turn is destroyed in a succeeding age. The other cause of imperfection is, that extensive areas are always sinking (to allow new deposits to be formed over them), and are being subjected to subterranean heat to such an extent as to change their texture and obliterate their fossils, when they become crystalline or metamorphic rocks. The more recent deposits so acted on will rarely have had time to have become raised above the sea-level, and subsequently exposed by denudation; yet certain Eocene strata in the Alps are stated by Sir C. Lyell to be truly metamorphic (*Students' Elements of Geology*, p. 600). The older a formation is, therefore, the more frequently will it have been exposed in one area or another to this metamorphic action; and it follows that, going backward in

time, we shall at last come to a period, all the formations antecedent to which will have become metamorphosed, and their fossils, if any, obliterated. We appear to have almost reached such a state of things at the base of the Palæozoic rocks; and there is good reason to believe that an extensive series of fossiliferous deposits may have once existed, whose record of the earlier stages of the history of life upon the earth has been either destroyed by denudation or obliterated by internal heat. This being the case, we must carefully distinguish between positive and negative evidence; and we may also fairly apply such principles as can be established by means of the fuller record afforded by the Tertiary deposits, to interpret the more scanty and fragmentary record with which we have to deal in the older rocks. We will now proceed to sketch very briefly the successive stages of the development of animal life as indicated by the materials at our command.

The lowest and most ancient of all the stratified rocks is the Laurentian, consisting of crystalline beds of gneiss, micaschist, quartzite, and limestone, reaching in Canada the aggregate thickness of 30,000 feet. The whole mass was long thought to be destitute of organic remains, till in one of the beds of limestone in the lower part of the series a curious structure was discovered, which is held by Dr. Carpenter and Professor Rupert Jones, who have made a special study of the Foraminifera, to be the fossilized remains of one of that group of the Protozoa. It has been named *Eozoön canadense*, and if really organic (which is denied by some naturalists of eminence) is by far the oldest trace of animal life. The Upper Laurentian deposits, 10,000 feet thick, lie unconformably on the lower, and seem to be entirely destitute of fossils.

The next formation is the Cambrian, largely developed in Wales, Scandinavia, Bohemia, and North America, and consisting of a variety of distinct deposits. But in the very

lowest of these (the Longmynd group) abundant organic remains have recently been found, comprising perfectly developed brachiopodous and pteropodous Mollusca, entomostracous Crustacea, and Trilobites. In the overlying beds of the same formation similar forms abound, and are accompanied by sponges, annelids, graptolites (which are supposed to be peculiar extinct Hydrozoa), star-fishes, and encrinurites. Here also first appear lamellibranchiate Mollusca, belonging to the families *Arcaide*, *Nuculide* and *Atlantide*, and there are even some *Orthoceratide*, belonging to the highest order of molluscs—Cephalopoda. The Trilobites are already wonderfully varied, the smallest and largest kinds being found here (one 2 feet long), species with the least and with the greatest number of rings, blind Trilobites, and others with the most largely developed eyes. (Lyell's *Students' Elements of Geology*, pp. 483, 485, 634.)

We next come to the Silurian formation, in which we first meet with corals, of the three great divisions Rugosa, Tabulata, and Perforata,—ostracode Crustaceans, Trilobites in enormous variety, Merostomata—extinct Crustaceans of gigantic size, Echinoidea (*Palæchinus*), and true gasteropodous Mollusca. And lastly, in the Upper Silurian deposits, we find vertebrates, whose first representatives are several genera of fishes belonging to the Ganoid and Plagiostomous groups.

In the succeeding Devonian formation we find an abundance of new families of fishes, a fresh-water mussel of the living genus *Anodon*, and no less than six forms of winged insects. These have been found in the Devonian rocks of New Brunswick, and are considered by Mr. Scudder to be ancient forms of Neuroptera.

The Carboniferous formation is very rich in animal as well as vegetable remains; and, along with most of the animals already met with, we find several higher types of great interest. The higher macrurous Crustacea (*Anthræpalæmon*) are here first met with,

as are true air-breathing molluscs, numerous specimens of the living genera, *Pupa* and *Zonites* having been found in the coal-fields of Nova Scotia. Along with these are insects of various orders—Myriapoda, scorpions, spiders, Orthoptera, Neuroptera, Coleoptera, and even Lepidoptera. Here, too, we meet with air-breathing vertebrates—the Labyrinthodonts, ancient forms of Amphibia which occur in considerable abundance and variety. (Lyell's *Students' Elements*, p. 408; *Annales de la Société Entomologique de Belgique*, 1875, tom. xviii., where a wing from the coal-measures, closely resembling those of moths belonging to the family *Saturniide*, is photographed.)

In the Permian formation, which closes the series of Palæozoic rocks, we have the important addition of true Lacertian reptiles (*Protorosaurus*), which, according to Professor Huxley, differ wonderfully little from some living groups. What are supposed to be Chelonian footprints have been discovered in the Permian sandstones of Dumfriesshire. (Huxley's *Lectures on Evolution*, HUMBOLDT LIBRARY edition, p. 15.)

Entering the Secondary period with the Triassic formation, we at once meet with higher forms of life. Among Crustacea we first find traces of the brachyurous division of Decapods (Etheridge, in Lyell's *Students' Elements*, p. 632) and many new forms of Mollusca. Among reptiles the Dinosauria, Dicynodontia, Plesiosauria, and Crocodilia appear; what seem to be undoubted footprints of birds have been found in the New Red Sandstone of Connecticut (see figures in Lyell's *Students' Elements*, p. 371, and Nicholson's *Palæontology*, p. 389); and all improbability of this early appearance of birds is removed by the fact that a little higher in the same formation remains of a true Mammalian have been undoubtedly discovered. This is the *Microlestes*, founded on well-preserved teeth from a bone bed in the Upper Trias of Würtemberg, and since found also in the Rhætic

beds of Somersetshire; while in rocks supposed to be of the same age in North Carolina the lower jaw of an allied form (*Dromatherium*) has been obtained. Both are believed to be Marsupials, and most nearly allied to the *Myrmecobius* of Australia.

In the Jurassic or Oolitic period, the main forms of life which have already appeared are further developed. Insects of all orders are found, and they can mostly be classed in existing families and even genera, as—*Locusta*, *Nepa*, *Sphynx*, *Termes*, *Ephemera*, *Agrion*, *Aeshna*, *Prionus*, *Libellula*. (Rev. P. B. Brodie, in *Proc. Warwickshire Nat. Hist. Soc.*, 1873.) Among reptiles, *Chelonia* and *Ichthyosauria* are added. Of birds we have the long-tailed and feathered *Archæopteryx*; while no less than eight genera of small Mammalia have been discovered, most of them Marsupials, though some may have been ancestral forms of Insectivora. Many living genera of shells, both marine and fresh-water, first appear; among fishes, true sharks of the existing family *Notidanidæ*.

In the Cretaceous period, we make a still further approach to living forms. The highest Crustacea (*Brachyura*) are tolerably abundant, and the living genus *Cancer* appears. Mollusca (*Lamellibranchiata* and *Gasteropoda*) are represented by a number of living genera. Malacopterous fishes now appear. Reptiles are still mostly of extinct types—*Pterosauria*, *Ichthyosauria*, *Dinosauria*, etc.; but among birds we find some allied to existing waders, as well as the curious extinct group of *Odontornithes*, or toothed birds. (Marsh, in *American Jour. of Science and Arts*, vol. x., 1875.)

When we pass over the great chasm of time which separates the Mesozoic from the Cainozoic or Tertiary period, we at once come upon a host of new forms closely resembling those which now live upon the earth. The majority of living genera of Mollusca now appear, with a gradually increasing proportion of living species, as we pass from the Eocene to Miocene and Pliocene times; the highest forms of

Crustacea are plentiful; Insecta of all orders, and almost all of living genera abound; fishes of living genera gradually appear, and true snakes (*Ophidia*) are first met with. Among birds, all the existing orders, many families, and some living genera appear in the Miocene period. Mammalia, however, exhibit the most surprising advance. Ancestral forms of all the existing orders are found in the Eocene formation: in the Miocene, most living families are well developed; while in the Pliocene and post-Pliocene deposits we find the genera and species for the most part closely resembling those that still inhabit the earth. The following diagrammatic table will enable the reader better to comprehend the main facts which we have here endeavored to set forth. It comprises only the larger or more important groups of animals, and of each of these the known range in time is indicated by a thick line. It has not been attempted to show the breaks which occur in our knowledge of the range of a group, since no one now doubts that where any type appears in two remote periods it must have been in existence during the whole intervening period, although we may have no record of it. Neither has it been attempted to indicate the abundance or scarcity of the group in each period, this being a detail suited only to a special treatment of the science of palæontology. It must also be remembered that it is often impossible for us to determine whether the increased prevalence of fossil remains of a particular group is due to a really greater development of the animals, or only to more favorable conditions for their preservation and discovery.

On considering the successive phases of animal life presented to us by the fossil remains preserved in the rocks, we cannot help perceiving that there has been on the whole a steady advance in organization and an increase in variety and complexity, from the earliest geological periods to the present day. Thus the oldest known

There are, it is true, many anomalies, the higher and more complex organisms in some of the minor groups appearing before the lower; but these cases generally occur in the oldest (Palæozoic) formations, where, on the principles already laid down, the record must be necessarily more imperfect. In the Mesozoic and Tertiary formations the succession is more regular, and accords better with the grade of organization of the several groups, and the best examples of this are to be found among the Mammalia of the Tertiary period, the series of which is, in some groups, tolerably complete. Thus, among the Ungulata we find in the Eocene deposits the remains of a number of generalized types, such as the *Palæotherium*, allied to the horse, tapir, and rhinoceros; *Lophiodon*, an ancestral form of tapir; *Anoplotherium* intermediate between pigs and ruminants; *Platylophus*, allied to the tapir and horse; and the North American *Orohippus*, a remote ancestor of the horse.* This last named animal, Professor Marsh tells us, had four toes in front and three behind, and was no larger than a fox; yet an almost perfect series can be traced, in succeeding deposits, of animals with smaller and smaller lateral toes, the size and speed increasing, the head and neck becoming longer, the canine teeth decreasing in size, the bones of the fore-arm consolidating, and other modifications successively taking place till we come, by almost imperceptible gradations, to an animal so completely unlike the one we started from as our existing horse. In like manner we have the extinct families of the *Anolotheridæ*, *Anthracotheridæ*, *Oreodontidæ*, and many groups of doubtful affinities, which seem to be ancestral forms from which sprung the swine, hippopotami, and all our ruminants. These become more specialized in the Mio-

cene; but it is only in the later Miocene and Pliocene that we find true deer, camels, oxen, and antelopes. So, the oldest form of the Carnivora, found in the very lowest bed of the Eocene formation, is the *Arctocyon*, one of the generalized types which cannot be referred to any existing family. A little later the *Canidae* and *Viverridæ* appear, while the more specialized and highly organized *Felidæ* are not found till the Miocene period. To exhibit in detail the succession and affinities of extinct forms is the province of palæontology; we can here only give the chief facts in outline, which however are sufficient to render intelligible the great principle which almost all palæontologists have arrived at, viz.—that extinct animals exhibit more generalized structures, as compared with the more specialized structures of recent animals. (Owen's *Palæontology*, p. 406.)

Having now laid before our readers a sketch of the more important facts of the distribution of animals in time, we will conclude this branch of our subject with a brief discussion of its bearing on the theory of evolution, and on the imperfection of the geological record. The abruptness with which animal remains in considerable variety first appear in very ancient deposits is undoubtedly a most remarkable phenomenon. With the exception of the still somewhat doubtful *Eozoön*, the vast series of Laurentian rocks have produced no fossils. But the moment we enter the Cambrian formation we at once meet with a somewhat extensive series of complex and varied organisms. Besides the Brachiopoda we have Pteropoda, a by no means low form of Mollusca; while the Trilobites and Phyllopodæ exhibit a considerable amount of specialization. Almost as early, we have sponges, annelids, star-fishes, encrinurites, lamellibranchiates, and Orthoceratidæ,—a variety of divergent and complex types, which, on any theory of development, indicates a very long succession of ancestral forms. But

* A still more remote ancestral form *Eohippus* has since been discovered in the lowest Eocene deposits of West America. See Huxley's *Lectures on Evolution*, HUMBOLDT LIBRARY edition, p. 35.

we must also bear in mind that the few fossiliferous deposits of this early age cannot possibly have made us acquainted with more than a minute fraction of the organisms which then existed on the whole earth. We are therefore compelled to believe that the absence of all remains of more ancient forms of life in the pre-Cambrian rocks is fallacious, and due solely to no record of them having been preserved, or, if preserved, to their not having been discovered by us. This conclusion is supported by analogous facts which occur and recur in every succeeding formation. The highly specialized corals and fishes of the Silurian rocks must have had ancestors in Cambrian times of which we know nothing; and the sudden appearance of perfectly developed winged insects in the Devonian formation, plainly tells us that during countless unrecorded ages various lower forms of terrestrial Annulosa must have been gradually developing into these marvelously specialized types,—yet these lower forms (Myriapods, etc.) only appear as fossils in the succeeding Carboniferous formation. Such highly organized insects also imply the existence of vegetation, and, by analogy, of other terrestrial animals of an equally high grade of development. Hence the discovery of these winged insects (which can, with great probability, be classed in one of our existing orders—the Neuroptera) opens up to the imagination of the evolutionist a wonderful picture, far removed from the dreary waste of waters which was once thought to characterize the epoch of the early Palæozoic formations. Geologists, indeed, have long taught us that the vast piles of sedimentary rocks of the Silurian, Cambrian, and even the Laurentian period necessarily implied the co-existence of extensive continents or islands whose denudation could alone produce them; and now the theory of evolution enables us to clothe these ancient lands with vegetation and people them with animal life, since it is only thus that

we can find space and time sufficient for the development of the wonderful insects, the land-shells, the Amphibia, and the reptiles,—all of which appear suddenly, in perfect and completely organized forms, in some parts of the Palæozoic series. When we consider that we have indications of the existence during the Carboniferous age of such diversified and highly specialized types of Annulosa as myriapods, spiders, cockroaches, locusts, dragonflies, ephemeras, lamellicorn-beetles, and bombyciform moths,—so that it is highly probable that no fresh ordinal type of insects has originated during all succeeding ages, and when we further consider that all these are specialized modifications of simple Annulosa, we shall be forced to conclude that, whatever time may have elapsed from that epoch to the present day, a far longer time is required, antecedent to the Carboniferous period, to allow of the development of such varied terrestrial forms of life.

As bearing upon this question it is important to consider how scattered and fragmentary are the few indications of mammalian life older than those of the Tertiary period. Sir Charles Lyell tell us, that up to the beginning of the present century it was a generally received dogma in geology that the Mammalia had not been created before the Tertiary period; and the first discovery of the jaw-bone of a small Marsupial in the lower Oolite caused as much sensation as would now be excited by our finding a Secondary monkey, or (we may add) a Silurian bird or mammal. The following table is abbreviated from that in the *Students' Elements* (p. 315), as it is well calculated to show how scanty and accidental is our knowledge, and how necessarily imperfect must be the geological record in still earlier periods.

For an account of the characteristics of these small animals, and for some details of their history, we refer the reader to Sir Charles Lyell's work; it is here only necessary to state the circumstances under which

SECONDARY STRATA.	Number of species.	Locality.	First Discovery.
Maestricht chalk	0	..	..
White chalk	0	..	..
Chalk marl	0	..	..
Upper Greensand	0	..	..
Gault	0	..	..
Neocomian (Lower Greensand)	0	..	..
Wealden	0	..	..
Upper Purbeck Oolite	25	Swanage	1854
Middle Purbeck Oolite	0	..	..
Lower Purbeck Oolite	0	..	..
Portland Oolite	0	..	..
Kimmeridge clay	0	..	..
Coral rag	0	..	..
Oxford clay	0	..	..
Great Oolite	4	Stonesfield	1818
Inferior Oolite	0	..	..
Lias	0	..	..
Upper Trias (Somerset, N. Carolina)	4	Würtemberg	1847
Middle Trias	0	..	..
Lower Trias	0	..	..
PRIMARY STRATA.			
Permian	0	..	..
Carboniferous	0	..	..
Devonian	0	..	..
Silurian	0	..	..
Cambrian	0	..	..
Laurentian	0	..	..

these remains have been preserved and discovered. Fossil remains of land animals are, of course, rarely found except in lacustrine or estuarine deposits; and these are often entirely wanting throughout extensive geological formations. But even where such fossiliferous beds occur, the conditions favorable to the preservation of small Mammalia are exceedingly rare,—the entire series of fresh-water Wealden beds having yielded no trace of them, although we are quite certain that they were then both varied and abundant. Even more remarkable is the fact that the whole 25 species of Purbeck mammals, belonging to 10 genera, were obtained from a single stratum only a few inches thick, and from an area of less than 500 square yards. Yet these small animals must have abounded at this period; and it is impossible to believe that anything but a most imperfect and fractional representation of the mammalian fauna of the country could have been gathered into this narrow graveyard. But this thin stratum occurs amid a mass of fresh-water deposits 160 feet thick,

the whole of which have been thoroughly and systematically examined by the officers of the Geological Survey of Great Britain; and though many of the layers contain remains of land organisms—plants, insects, and land-shells—no other part of the whole series has yielded a single fragment of mammalian remains! Having this striking example of the worthlessness of negative evidence, it behoves us to be cautious of rejecting any legitimate conclusions from the facts in our possession, on account of the absence of the direct evidence of fossil remains. The varied and highly-developed Mammalia of the Eocene period really necessitate (to the evolutionist) the long-continued previous existence of this class of animals; and the discovery of isolated species in the Oolite and Trias would (had it been delayed to our time) have been but a confirmation of theoretical deductions.

In his anniversary address to the Geological Society in 1870, Professor Huxley adduces a number of special cases showing that, on the theory of development, almost all the higher forms of life must have existed during the Palæozoic period. Thus, from the fact that almost the whole of the Tertiary period has been required to convert the ancestral *Orohippus* into the existing horse, he believes that, in order to have time for the much greater change of the ancestral Ungulata into the two great divisions of Perissodactyles and Artiodactyles (of which change there is no trace even among the earliest Eocene Mammals), we should require a large portion, if not the whole, of the Mesozoic period. Another case is furnished by the bats and Cetacea, which occur fully developed in the Eocene formation; and these would have required still more time for their modification out of ancestral Insectivora and Carnivora. The Marsupials of the Trias, again, were already differentiated into herbivorous and carnivorous forms; so that on the lowest estimate we must place the common ancestor of

the Mammalia very far back in Palæozoic times. Reptiles furnish evidence of the same character. Professor Huxley says, "If the very small differences which are observable between the *Crocodylia* of the older Mesozoic formations and those of the present day furnish any sort of approximation towards an estimate of the average rate of change among the *Sauropsida*, it is almost appalling to reflect how far back in Palæozoic times we must go before we can hope to arrive at that common stock from which the *Crocodylia*, *Lacertilia*, *Ornithoscelida*, and *Plesiosauria*, which had attained so great a development in the Triassic epoch, must have been derived." And if to these indications we add the appearance of two orders of fishes—Elasmobranchs and Ganoids—in the Silurian period, we shall be compelled to place the origin of the whole vertebrate stock at an epoch far beyond that of the lowest fossiliferous rocks of the Cambrian series.

If, then, we bear in mind the very early appearance of so many highly complex organisms, representing all the great types of animal life—almost all the great invertebrate groups in the Cambrian and Lower Silurian, with many Vertebrata and almost all forms of Insecta in the Devonian and Carboniferous periods,—while a large number of these have hardly increased in complexity of organization down to our times, we shall be prepared to admit the extreme probability of Mr. Darwin's view, that "before the lowest Cambrian stratum was deposited, long periods elapsed—as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures" (*Origin of Species*, HUMBOLDT LIBRARY ed. par. 555).

Professor Ramsay has recently expressed analogous views, founded on an extensive survey of the whole series of geological formations. In a paper "On the comparative value of Certain Geological Ages (or Groups

of Formations) considered as items of Geological Time" (*Proceedings of the Royal Society*, 1874, p. 334), he says—speaking of the abundant and well-developed fauna of the Cambrian period, a sketch of which we have given at pp. 31, 32 :—"In this earliest known *varied* life we find no evidence of its having lived near the beginning of the zoological series. In a broad sense, compared with what must have gone before both biologically and physically, all the phenomena connected with this old period seem, to my mind, to be of quite a recent description; and the climates of seas and lands were of the very same kind as those the world enjoys at the present day."

It thus appears that the general geological principle with which we started, of the more complete destruction by denudation and metamorphism of the earlier as compared with the later records of life upon the earth, receives ample support in the apparently sudden appearance of whole groups of complex and specialized forms in some of the earliest rocks; while the general imperfection of the geological record is made manifest by such facts as the very few and isolated remains of Mammalia in the Mesozoic rocks, although we know they must have existed in abundance throughout the whole Secondary and much of the Palæozoic periods. The great lesson we have to learn from the facts of palæontology is, that its negative evidence is at the best of but little value; but when this negative evidence is opposed to general principles established upon a wide basis of physical and biological research, it becomes absolutely worthless. Just in proportion as the series of fossiliferous deposits is more complete, and the fossil remains more abundant and varied, does the evidence for evolution and progressive development become more powerful. The difficulties are almost wholly dependent on incomplete knowledge, and on the assumption (which we have endeavored to show is entirely

unfounded) that the earliest traces of the fossil remains of any animal type which have been discovered can give, even approximately, the period of its first appearance upon the earth.

We find, then, that just as a study of the distribution of animals in space enables us to learn much of the immediately preceding condition of the earth's surface, and especially of the recent changes of land and water,—so a study of the distribution of animals in time, when aided by the modern theory of evolution, gives us some knowledge of the physical condition and life of the earth in times beyond the reach even of geological history.
—A. R. W.

SECTION II.

DISTRIBUTION OF VEGETABLE LIFE.

THE literature in which the immense multitude of distinct kinds of plants which are dispersed over the earth's surface and form its vegetation has so far been described has necessarily been adapted to the divisions of political geography. The causes which have brought about the formation of such divisions have rarely, however, had anything in common with those which have determined the characteristic features, whether superficial or profound, of the floras of different countries. The great mass of catalogues and descriptive enumerations of the plants of such countries, the boundaries of which are for the most part quite artificial, are therefore ill adapted for bringing out any general conclusions as to the mode in which plants are distributed. It is only by making some kind of analysis of the often heterogeneous contents of such catalogues, and piecing together the results obtained from different sources, that any clue can be obtained to the approximate lines of demarkation of floras which are really naturally limited and characterized. The process is, however, enor-

mously laborious, and, even apart from that, must for a long time to come be exceedingly imperfect in its application, owing to the immense tracts of land—and those with the most varied and copious vegetation—of the natural products of which our knowledge is still most defective.

Numerous attempts have, however, been made, notwithstanding the difficulty of the task, to map out the earth's surface into "regions of vegetation." The real significance of these regions will, of course, entirely depend upon the principles which have been relied upon in forming them. And in this respect the progress of geographical botany has been exactly similar to that of classification. The characteristic distinctions which were first seized upon in either case proved on closer scrutiny to be superficial, and to bring about merely artificial and arbitrary assemblages. The doctrine of evolution has in fact effected the same revolution in both; it has shown in the one that community of descent is the real meaning of a natural classification; it has shown in the other that community of origin is the real key to geographical distribution.

Most of the writers on geographical botany have been content, to set aside all considerations of origin and history in attempting to define the limits of botanical regions. They have not attempted to see in the peculiar features which such regions may possess anything more than adaptations to physical conditions working on plants created in great measure where they are found. Although, therefore, the literature of geographical botany has been useful in enabling the reader to realize the local features—the coloring, if one may so express it—of particular countries, the facts have hitherto been presented in a form void of any true significance. And these remarks apply to the system of Schouw (1833), which has been much employed, partially to that of De Candolle, and conspicuously to that more recently

published by Grisebach. It is to the writings of Darwin, Hooker, Asa Gray, and Bentham that we must look for a real insight into the origin and dispersion of floras, and for the real causes of the existing distribution of plant life.

The first attempt to review the whole subject of plant-distribution from the modern point of view afforded by evolution is due to Bentham, who made it the subject of a presidential address delivered to the Linnean Society in 1869. Bentham's conclusions are based upon the experience of a long life devoted to systematic botany, and will probably always hold a fundamental position in the study of the subject; at any rate for some time to come, until the distribution of a large number of subordinate groups has been carefully worked out, the main points established by him are not likely to be materially modified.

The general *faûes* of vegetation is obviously largely affected by purely physical causes. In the polar regions, arboreal and even shrubby plants become incapable of existence, and only small perennials which are safely covered up by snow during the long winter are able in the brief summer to expand their flowers and ripen their seeds. Putting aside for the moment the severances effected by large bodies of water and mountain chains, it is easy to see that the vegetation of the earth must have always been separable into three great latitudinal zones, two belonging to the north and south hemispheres respectively, and one dividing them lying between the tropics. The constituents of the vegetation of these zones must always have had a certain homogeneity; very considerable divergences, however, have grown up within the zones themselves, owing to circumstances of geographical isolation. Even without these, distance alone, independently of isolation, would in time be sufficient to effect it. It is also obvious that the precise northern and southern limitations of such hy-

pothetical zones must have varied with secular changes in the earth's climate, and when these changes have taken place over a broken configuration of land and sea, the intermixture of diverse floras must necessarily have become very complicated.

Underlying, however, the tangled fabric of the earth's existing floral covering, we may agree with Bentham* in recognizing the existence of three tolerably ancient floras—the Northern, the Tropical, and the Southern.

I. The Northern is characterized by its needle-leaved Coniferæ, its catkin-bearing *Amentacæ* and other forest trees deciduous in winter, and its vast assemblage of herbaceous types, *Ranunculacæ*, *Cruciferae*, etc. These spread over Europe, northern and central Asia, and great part of North America.

II. The Southern is broken up into numerous divergent floras. Their original connection is now traceable only in the common possession by two or more of them of large characteristic groups, such as *Restiacæ*, *Proteacæ*, *Diosmeæ*, etc., the subordinate divisions of which have been locally specialized. To this belong the floras of extra-tropical South America, South Africa, and Australia with New Zealand, to which must probably be added an area borrowed from the northern hemisphere in Mexico and California.

III. The Tropical is characterized by the predominance of mostly evergreen arborescent *Polypetalæ* (*Anonacæ*, *Meliacæ*, *Leguminosæ*, etc.), and gigantic Monocotyledons, of which Palms, *Scitamineæ*, and *Bambusæ* among grasses are especially striking.

I. THE NORTHERN FLORA.—This has been long divided into that of Old and New World by the severance of North America from Northern Asia, and by the barrier to an interchange of vegetation in the upheaval of the Rocky Mountain range. Nevertheless its marked continuity (with only

* Presidential address to Linnean Society, 1869, p. 18.

a gradual east and west change in the arctic regions, but an increased divergency southward) requires it to be treated as a whole. The Old and New World divisions of this flora, which, no doubt, began to diverge from the mere influence of distance, have now had that divergence immensely increased by isolation. According to Lesquereux,* the essential types of the present arborescent flora of North America are indicated in the Cretaceous rocks of that country, and become more distinct and numerous in the Tertiary; and he believes that the origin of the existing American flora is American. The analogy between the Miocene flora of Central Europe and the present North American flora is unquestioned, and is greater than between the same fossil flora and that now existing in Europe. Lesquereux's conclusion is that the American element in the vegetation of Miocene Europe was derivative, and this is one of many illustrations of the curious observation of Asa Gray that plants have in general a greater tendency to migrate from east to west than from west to east. This Miocene flora was, however, gradually driven back again, and it is only as we travel from Europe to the East that we gradually find its traces getting stronger and stronger. Thus, as Oliver† has pointed out, in passing from the Mediterranean to the Levant, the Caucasus, and Persia, we meet with living representatives of the Miocene genera *Chamerops*, *Platanus*, *Liquidambar*, *Pterocarya*, *Juglans*, etc. Along the Himalayas and through China we trace other Miocene genera, Japan forming part of the same botanical region as Eastern Asia. Among the remarkable existing North American types which may be mentioned as reappearing in the Himalayas and Japan are *Aralia quinquefolia*, *Phryma leptostachya*, and *Trillium erectum*. One of the most interesting additional facts which has

recently come to light is the occurrence of a species of tulip tree (*Liriodendron*) in Central China, which genus, though a member of the European Miocene flora, has in recent times been regarded exclusively characteristic of America.* With respect to other American genera which are not necessarily part of the Miocene flora, the same general principle holds good. Bentham remarks, that while some, like *Astragalus*, have multiplied largely in both continents, "other genera, like *Eupatorium*, *Aster*, *Phlox*, *Solanum*, etc., very numerous represented in America, have transmitted or produced a smaller number in Eastern Asia, gradually diminishing westward till they disappear altogether or attain Western Europe in single species but little altered from American ones."† The Europeo-Asiatic genera, on the other hand, such as *Cruciferae*, *Umbelliferae*, etc., which are so dominant a feature in the existing Old World Northern flora, appear "to have left but few representatives in America, and those much more modified than the American races left in Asia."

Besides the internal migrations of the various constituents of the great Northern flora, its boundaries have been changed longitudinally under the influence of secular variations of climate alluded to above. The nature of these cannot be better summed up than in the words of Bentham:—‡

"Where the chief portion of this great northern flora originated, and whether it may be best termed Scandinavian, or North Asiatic, or Caucasian, is a question for the determining of which we have little or no data; but, as observed by Hooker, it is probably one of the most ancient and widest spread, having at different epochs traveled over a great part of the globe. Shown by the researches of Lesquereux, as well as by the recent ones of Heer and others, to have extended far north during the warmest preglacial times, it must have been

* Moore, *Journ. of Bot.* 1875, p. 225.

† Presidential address, 1869, p. 18; see also Bentham in *Journ. Linn. Soc. Bot.*, xiii. p. 500.

‡ Presidential address, 1869, p. 19.

* *Geological Survey of Montana*, 1871, p. 314.

† *Nat. Hist. Rev.* 1862.

slowly driven southward as the glacial epoch came on, and either then, or at some one or more other periods, have been for a time continuous, in two lines at least, into the southern hemisphere; for it has left traces still discernible, especially in its herbaceous and mountain forms, in the mountains of tropical Asia, down at least to the Indian peninsula, and westward to the Abyssinian and Cameroons mountains of Africa, and again, down the Andes to the extreme south of America, where it is still luxuriant, and in a less degree in New Zealand, Tasmania and Victoria. In all these migrations, while retaining a general identity, the flora must have undergone continual changes, losing species or other races of limited areas and propagation as their habitations became unfit for them, and gradually forming new ones when favored by long continued isolation or other requisite conditions."

The Northern flora has further undergone a specialization into three secondary floras, due to the combined influence of physical and genetic causes.

The *Arctic-alpine* flora ("consisting chiefly of plants of small stature, slow growth, and limited means of dispersion, compensated by long lives and great powers of endurance") is perhaps the most interesting of the three subdivisions, both because in its arctic aspect it reduces the divergence of the Old and New World divisions of the Northern flora to a minimum, and more especially on account of the great interest which attaches to the problem of its scattered alpine outliers. With regard to the first point, Hooker found that estimating the whole Arctic flora at 762 species, Arctic East America possessed 379, of which 269 were common to Scandinavia. Of the whole flora 616 species are found in Arctic Europe, and of these 586 are Scandinavian, and this leads Hooker to the striking observation that "the Scandinavian flora is present in every latitude of the globe, and is the only one that is so."* Christ objects to

Hooker's giving the title of Scandinavian to the Arctic flora, but we must agree with Bentham* that Scandinavia "would, according to older rules, have been regarded as the centre of creation for the arctic lands, and may now be termed the chief centre of preservation within the arctic circle, owing perhaps partly to its more broken conformation, and partly to that warmer climate which, while it now admits species which Christ objects to being included in the Arctic flora, was during the glacial period a means of preservation of some colder species which were everywhere else expelled or destroyed."

Just as at present the Arctic is more homogeneous than the more southern divisions of the Northern flora, so we may infer that toward the close of the Tertiary epoch the continuous circumpolar land was covered with a vegetation also largely composed of identical plants but adapted to a warmer climate. As the climate became less warm there would commence a migration southward, which would result in the modified descendants of these plants being now blended with the vegetation of Central Europe and the United States. As the glacial period gradually advanced, "the tropical plants and animals will have retreated from both sides toward the equator, followed in the rear by the temperate productions, and these by the arctic."† When the climate of the earth again ameliorated, the migration took place in the reverse direction, and in this way mountain ranges became the havens of refuge of fragments of the original arctic floras which were exterminated on the lowlands. Even the equatorial region ceased to be a barrier during the glacial period, and to migration at that time must be attributed the survival of arctic forms in the south temperate zone. The southern migration of the Arctic flora does not appear to have taken place

* Hooker, on the "Distribution of Arctic Plants," *Trans. Linn. Soc.*, vol. xxiii. p. 253.

* Presidential address, 1860, p. 21.

† Darwin, *Origin of Species*, 4th ed. p. 447.

in one continuous wave. Thus, as Bentham points out,* "many facts showed separate communications between the north and each of the three chains of the Pyrenees, the Alps, and the Himalayas, while these three gave little evidence of any lateral communication of their respective alpine vegetations."

The fact that the migration southward and remigration northward of the Arctic flora took place along parallels of longitude, accounts for some of its existing peculiarities. Hooker explains in this way the comparative poverty of the Greenland flora.†

"If it be granted that the polar area was once occupied by the Scandinavian flora, and that the cold of the glacial epoch did drive this vegetation southward, it is evident that the Greenland individuals, from being confined to a peninsula, would be exposed to very different conditions to those of the great continents. In Greenland many species would, as it were, be driven into the sea, that is exterminated; and the survivors would be confined to the southern portion of the peninsula, and not there being brought into competition with other types, there could be no struggle for life among their progeny, and consequently no selection of better adapted varieties. On the return of heat, these survivors would simply travel northward unaccompanied by the plants of any other country.

"In Arctic America and Asia, on the other hand, where there was a free southern extension and dilatation of land for the same Scandinavian plants to occupy, these would multiply enormously in individuals, branching off into varieties and sub-species, and occupy a larger area the further south they were driven; and none need be altogether lost in the southern migration over plains, though many would in the struggle that ensued when they reached the mountains of those continents and were brought into competition with the alpine plants, which the same cold had caused to descend to the plains. Hence, on the return of warmth, many more Scandinavian species would return to Arctic America and

Asia than survived in Greenland; some would be changed in form, because only the favored varieties could have survived the struggle; some of the alpine Siberian and Rocky Mountain species would accompany them to the arctic zone; while many arctic species would ascend those mountains, accompanying the alpine species in their reascent."

The Arctic-alpine flora is obviously in its present condition a composite one. Portions of the Northern flora, probably originally very distinctly characterized became adapted to the peculiar physical conditions of high mountain ranges and of the extreme north. The gradual deterioration of the climate brought the alpine flora to the lowlands and the arctic flora southward till they intermingled. When they again returned to their original territories they were so far changed that each gave the other some new members, while both had experienced many losses.

A. de Candolle has very ingeniously applied the general principles laid down above to the detailed explanation of the distribution of the flora of the Alps themselves. The following is a brief summary of his conclusions:—*

The valleys and groups of mountains which have at present a maximum of rare species and the most varied flora belong to districts on which the glaciers disappeared earliest. On the other hand, where the duration of snows and glaciers has been most prolonged, the existing flora is poor. From a variety of causes which A. de Candolle enumerates, it seems probable that the southern and eastern glaciers of the Alps were of smaller extent than the northern, and would consequently be the soonest to retreat. We have consequently the curious fact that some of the most ancient fragments of the alpine flora are now only to be found on the southern slopes of the Alps. This is the case with species of *Primula*, *Pedicularis*, and *Oxytropis*, which exist neither in the interior of Switzerland, nor in the north of Europe. But it is easy to see that, like the

* Presidential address, 1869, p. 22.

† Hooker, *l. c.* p. 254.

* These are given in greater fullness in *Nature*, April 27, 1876, p. 526.

other members of this flora, they were driven south during the glacial period, returning as the mountains reappeared from underneath their snowy covering, while on the northern side they were in great measure exterminated. A. de Candolle points out as a fact in further confirmation that the Alpine species of *Campánula*, peculiar to Mont Cenis and the Simplon and neighboring valleys, are not related to the Arctic species, but find their nearest allies in Greece, Asia Minor, and the Himalaya.

A further indication of the great antiquity of the Arctic-alpine flora is afforded by the fact of its absence in the comparatively modern volcanic mountains of France. "The Monts d'Or and Cantal, at an elevation of 6000 feet, offer scarcely any of those alpine and sub-alpine plants which abound at the same or lower elevations in the Pyrenees on the one side, and in the Alps on the other, as well as in the British and Scandinavian mountains to the North."* Hooker, however, points out that the absence of the alpine-arctic flora in Auvergne may be due to severe glaciation rather than to its absence (see *Nature*, Nov. 11, 1875, pp. 31, 32).

The *Intermediate* or *Temperate* flora is best described in the words of Bentham as

"A mongrel vegetation of mixed origin, including a large proportion of species of the most extended geographical range, with a very few local ones, and those chiefly in the extreme west. The majority, whether trees, shrubs, or herbs, are plants of comparatively rapid growth, very prolific, endowed with great facilities for dispersion, and constitutions capable of adapting themselves to a great variety of physical and climatological conditions. They are great travelers, and soon take possession of any district left denuded by the abandonment of cultivation. To the great majority of them no primeval antiquity can be ascribed in Central or Western Europe; †

they appear to have come from the East, a considerable number perhaps from Western Asia, where their types appear to be more varied, but many also must have made half the tour of the globe. Large American genera have sent out offshoots into Eastern Asia, which gradually diminishing in number of species, and sometimes slightly modifying their character, have spread over the whole of Asia, and invaded almost every part of Europe. These plants are, moreover, generally continuous, that is, interrupted only by intervals which under present condition they have means of crossing; and they are abundant in individuals, ascending in latitude and elevation, or descending to the south, until checked in their career by competing species, better enabled to endure the increasing rigor or the searching drought of the respective climates. Many of them will even assume slight modifications suited to their exceptional circumstances, and it is then as difficult to separate them from the genuine northern or southern floras as in many cases to give plausible grounds for establishing the precise origin of individual species."*

The peat deposits of Denmark tell an unmistakable tale of the gradual advance of successive waves of vegetation from the south-east. The Scotch fir was once abundant within the Roman period in the Danish islands, but is now extinct; it was succeeded by the sessile-fruited oak, to be in turn supplanted by the pedunculated form of the same tree, associated with the alder, birch, and hazel. The oak is now almost supplanted by the beech.† According to Areschoug, the original post-glacial flora of Scandinavia has retreated to the north, and is probably still retreating, while the flora of central and south Scandinavia consists of "an eastern and north-eastern vegetation, which spread into Europe after the glacial period and before the beech tree had invaded Sweden, with the admixture of more southern species, which, with the beech, have since penetrated into Sweden through Denmark."‡ The beech and the chestnut

* Bentham, *Nat. Hist. Rev.*, 1864, p. 370.

† Martins, however, considers that many of the plants of the existing south of Europe flora are of great antiquity in their present situations; thus the Oleander (*Nerium Oleander*) has been found in deposits from the Eocene upward (*Mém. de l'Acad. d. Sc. de Montpellier*, ix. p. 93).

* *Nat. Hist. Rev.*, 1864, pp. 370, 371.

† *vell. Antiquity of Man*, p. 9.

‡ Bentham, *l. c.* p. 22.

occur in Japan, and, as far as Europe is concerned, there is good reason to regard their origin as Eastern.

As already pointed out, the American element in the European flora suffered severely during the glacial period, and has never since recovered itself. Japan, however, appeared to have been a great centre of preservation, and hence the numerous points of contact which its flora presents with that of the North American continent. In the New World itself, the continuity of the pre-glacial and post-glacial temperate floras has been better preserved. The following passage from an address of Asa Gray's may be quoted as giving its history in a concise form:—

He "considered that the present vegetation or its proximate ancestry must have occupied the arctic and sub-arctic regions in Pliocene times, and that it had been gradually pushed southward as the temperature lowered and the glaciation advanced, even beyond its present habitation; that plants of the same stock and kindred probably ranging round the arctic zone as the present arctic species do, made their forced migration southward upon widely different longitudes, and receded more or less as the climate grew warmer; that the general difference of climate which marks the eastern and western sides of the continents,—the one extreme, the other mean,—was doubtless even then established, so that the same species and the same sorts of species would be likely to secure and retain foothold in the similar climates of Japan and the Atlantic United States, but not in intermediate regions of different distribution of heat and moisture; so that different species of the same genus, as in *Torreya*, or different genera of the same group as redwood, *Taxodium* and *Glyptostrobus*, or different associations of forest-trees, might establish themselves each in the region best suited to the particular requirements, while they would fail to do so in any other."*

The west of Europe possesses the remains of a local and probably more ancient flora of very great interest, characterized by Gorse, and allied shrubby *Leguminosæ*, Heaths, Lobe-

lias, Sibthorpias, etc. These are closely checked in any tendency toward eastern dispersion by the severity of the winter climate away from the ameliorating influence of the sea. The probability of a southern extra-tropical connection of this peculiar element in the Northern flora will be adverted to hereafter.

The flora of the British Isles is in many respects interesting; it is in its main features an extension of the Germanic area of the temperate flora with the presence of the western element above alluded to distinctly marked on the south-western coasts. *Eriocaulon septangulare* is an anomalous constituent, being limited to Ireland and a few islets on the western side of North Britain, and being otherwise an American and not a European species.* Its presence can hardly be explained except by the agency of migratory birds.

The *Mediterraneo-Caucasian* flora, like the Arctic alpine, contrasts in the most marked way with the temperate.

"By far the richest and most diversified in species [it comprises six-sevenths of the European flora], it is also remarkable for the great variations centering round individual types, as well as for the very restricted areas occupied by a number of the most marked species; the limits are not to be accounted for by any physical peculiarities we are acquainted with, nor perhaps to be otherwise explained than by a supposition of very great antiquity."

Eastward of the Caucasus this remarkable flora dies away, reaching its eastern limit in Scinde, and the temperate flora of Asia is only separated from the tropical by the Himalayas. Southward its progress is arrested by the arid zone formed by the African and Arabian deserts.† As in the case of the arctic flora, traces still exist of its former southern extension under the influence of a colder terrestrial climate. *Adenocarpus*, a characteristic Mediterranean genus, is

* *Darwiniana*, pp. 224, 225.

* Watson, *Compendium*, p. 31.

† Bentham, *Nat. Hist. Rev.*, 1864, p. 373.

represented by an identical species on Kilima Njaro, near the equator, and on the Cameroons mountains, 2000 miles distant on the opposite and western side of the African continent.*

II. THE SOUTHERN FLORA.—The Southern flora exhibits relations much more complex than those presented by the Northern. Instead of extending over large continental areas it is now dismembered into isolated groups scattered over the southern hemisphere, and in both the New and Old World sending northern extensions across the equator.

Five types may be briefly described, the definition of all but the first being taken from Bentham:—†

The *Antarctic-alpine* flora is the complement of the *Arctic-alpine*. It consists mainly of some widely-distributed northern genera such as *Carex*, *Poa*, *Ranunculus*, etc., with alpine types of strictly south temperate genera characteristic of the respective localities. Hooker describes it as possessing "decided Australian representatives in *Centrolepideæ* and *Stylidiæ*, commencing in Fuegia, the Falklands, and Lord Auckland's and Campbell's groups, reappearing in the Alps of New Zealand, Tasmania, and Australia, and disappearing under the equator, on the Alps of Borneo."‡

The *Australian* flora is "almost endemic, showing some slight connection with the New Zealand, and a few remains of former ramifications northward to some parts of the Indian Archipelago, a very few species, perhaps of modern introduction, extending to China and Japan." Bentham§ conclusively dismisses Unger's theory of the former extension of the Australian flora into Europe in Eocene times.

The *Andine* flora, characterized by a large number of distinct genera, *Fuchsia*, *Gaultheria*, *Calceolaria*, ranges more or less along the whole chain, "penetrating far northward in

Western America, throwing off a few branches into Eastern Asia, and at its southern extremity crossing over to New Zealand, and in smaller numbers to Tasmania, and the mountains of Victoria."*

The *Mexico-Californian* flora is "represented at great distances by closely allied species of small distinct genera—in Mexico and California, in the Argentine states, and in S. Africa or Australia."†

The *S. African* flora is "perhaps the richest known in proportion to its extent, and remarkably varied within its narrow limits." Its connection with other floras is very slight. That with Australia, alluded to at the commencement, does not extend beyond groups of the highest order (in the *Proteaceæ* not merely the species but the genera have become geographical); and, as mentioned above, there are a few scattered species, representing the South African flora, in extra-tropical South America. There are, however, two offshoots in a northern direction. The remarkable West European flora, already referred to, possesses species of *Erica*, shrubby *Leguminosæ*, *Lobelia*, *Gladiolus*, etc., "more nearly allied to corresponding Cape species than they are to each other." The other extension is to Eastern Africa. The sub-alpine vegetation of Kilima Njaro is distinctly South African, and Hooker suggests "the probability of the South African flora being represented all along the highlands of Eastern Africa from Natal to Abyssinia; and further, seeing that most of the South African plants found in the Cameroons are also natives of Abyssinia, it would appear probable that the migration of these to the Cameroons was by and through Abyssinia." The further suggestion that this may have been the path traveled by the West European extension of the South African flora is sufficiently obvious.

* Hooker in *Journ. Linn. Soc. Bot.*, xiv. p. 144.

† Presidential address, 1869, pp. 24, 25.

‡ *Introductory Essay to the Flora of Tasmania*, p. 104.

§ Presidential address, 1870, pp. 12-67.

* On the extra-tropical southern connection between America and the Old World as illustrated by the *Compositæ*, see Bentham in *Journ. Linn. Soc.*, xiii. p. 561.

† See also Asa Gray, *Darwiniana*, pp. 218, 219.

The amount of agreement among these scattered fragments of a great flora points necessarily to a state of things when the lands they now occupy were at one time or other in more or less of intimate connection. The amount of differentiation between the floras, and the fact that agreement has to be sought in groups of high rather than of small rank, points equally to the fact that such connections must have been far from recent.* The detailed study of separate groups leads by another path to the same result, and, as a good instance of the new phase into which taxonomic botany is entering in the light of the study of geographical distribution, reference may be particularly made to Bentham's important investigation into the past history and migrations of the *Campanulacæ*.†

III. THE TROPICAL FLORA.—This is still perhaps too imperfectly known to admit of any very plausible generalization. It obviously presents three great subdivisions.

The *Indo-Malayan* extends from the Himalayas to north-east Australia and Japan. In the latter country it meets the northern temperate flora, from which in India it is sharply divided by the Himalayas.

The *American* is still a perfect mine of unexplored botanical wealth. Bentham remarks—"No general comparison of Asiatic and American tropical vegetation can therefore be made without immense labor of detail. As far as we know, however, the resemblance between them is only in some of the races of a higher grade, natural orders and comprehensive genera; the smaller genera and species, and many even of the higher ones, are totally different; or if a few species are identical, they are generally, if woody or arborescent such as *Entada*, *Gyrocarpus*, etc., wholly or partially maritime, and may have traversed the ocean during its present configuration, or if herbaceous, widely spread weeds, still more likely to be

spread all round the tropics under existing conditions."* There are, however, some extraordinary points of connection between the tropical floras of the Old and New Worlds, to which there is at present scarcely any clue. Thus *Ternstroemia emarginata*, endemic to Ceylon, so closely resembles the Brazilian *Ternstroemia cuneifolia* as to be barely distinguishable.

The *African* tropical flora is probably the most imperfectly known of any. Bentham considers it as of great antiquity, and as having preserved large numbers of persistent types from which races "have widely diverged in Asia or America, or in both." He further remarks that "as our knowledge of the vegetation of tropical Africa has increased, we have discovered a greater number of Asiatic types; but still there are, even in the interior, a certain number of American ones, offering a problem the solution of which has scarcely been attempted."†

In *Compositæ* American genera are represented in east tropical Africa, and Bentham is led on various grounds to regard this as the principal area of preservation of the most ancient tropical flora of the Old World.‡ A well-marked eastern element in the African tropical flora is generally accepted. Madagascar, whose flora bears the marks of long isolation, contains Malayan and even Australian types, and it is a problem worth future inquiry whether the connection between the floras of tropical America and Africa may not have taken place south of the tropics, and by similar (though more northern) paths to those which once united the scattered members of the great Southern flora.

As might have been expected, during the Tertiary period the tropical flora extended much beyond its present limits. De Saporta, who has studied with great caution the fossil flora of the gypseous beds (Eocene)

* *Journ. Linn. Soc. Bot.*, xiv. p. 145.

† *Ibid.*, xv. p. 11.

* Presidential address, 1869, p. 24.

† *Journ. Linn. Soc. Bot.*, xlii. 545.

‡ Bentham, *l. c.* p. 24.

of Aix in Provence, arrives at the following conclusions:—The principal families were such as characterize tropical vegetation, especially Indian—*Ebenaceæ*, *Anacardiaceæ*, *Sapindaceæ*, *Sterculiaceæ*, *Leguminosæ*. The affinities of the ancient vegetation of Aix in respect of generic types, general facies, and composition with that of India and the Indian archipelago, China, the Philippines, and Japan at the present day, are in perfect accordance with the theory that these regions formed the shores of our ancient nummulitic sea, extending from Morocco to Japan, and entirely comprised in the tropical zone of the Eocene world, which extended to the 55th parallel. Besides its relation to South-Eastern Asia, the Aix flora exhibits, according to De Saporta, a strong affinity with that of Africa, lying between Abyssinia and the Cape, of which, however, it must be confessed, but little is as yet known.

Here this outline of the present state of a most important and rapidly developing branch of biological sci-

ence must be concluded. The writer has availed himself very freely of the kind permission of Mr. Bentham—perhaps the greatest living master of the subject—to make use of his scattered but invaluable papers, not scrupling to borrow from them all that seemed most important and suggestive, but has generally thought it fairer both to the subject and to Mr. Bentham to do so in his own words. For two heads of the subject it must suffice merely to give references. On the remarkable phenomena of insular floras, the reader should consult Sir Joseph Hooker's well-known lecture delivered before the British Association in 1866, and printed in the *Gardener's Chronicle* for January, 1867, or, in default of this, the summary given in Lyell's *Principles of Geology*, 10th ed., vol. ii. pp. 417–421. On the means of dispersion of plants, reference may also be made to Lyell's work already quoted, vol. ii. pp. 386–400; Darwin's *Origin of Species*, HUMBOLDT LIBRARY edition, par. 624–642; Bentham, Presidential Address, 1869, pp. 7, 8.—W. T. T. D.

* *Annales des Sciences Naturelles*, Sept. 1, 1872.

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